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ABSTRACT

This publication focuses on spinoff benefits of the National Aeronautics and Space Administration space program developments. The first of the three sections describes the direct benefits of space exploration and aeronautical research. Some of these direct benefits are expanding knowledge about our solar system and our universe, the development of a versatile and reusable shuttle craft, increased safety for commercial and private airplanes, improved weather prediction and pollution monitoring. The second section describes the secondary benefits of NASA's main programs. Many of these secondary benefits are commercially available or are in industrial use. Some secondary benefits described are solar heating and generating developments; more efficient home heating cooling, and construction; several computer assisted medical aids and programs; heat pipes for the Alaska pipeline; forest fire fighting aids; and packaged meals for the elderly. The third section describes how NASA Technology Utilization Office makes new technology available and encourages its use by others. (MR)

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Spinoff 1977

AN ANNUAL REPORT

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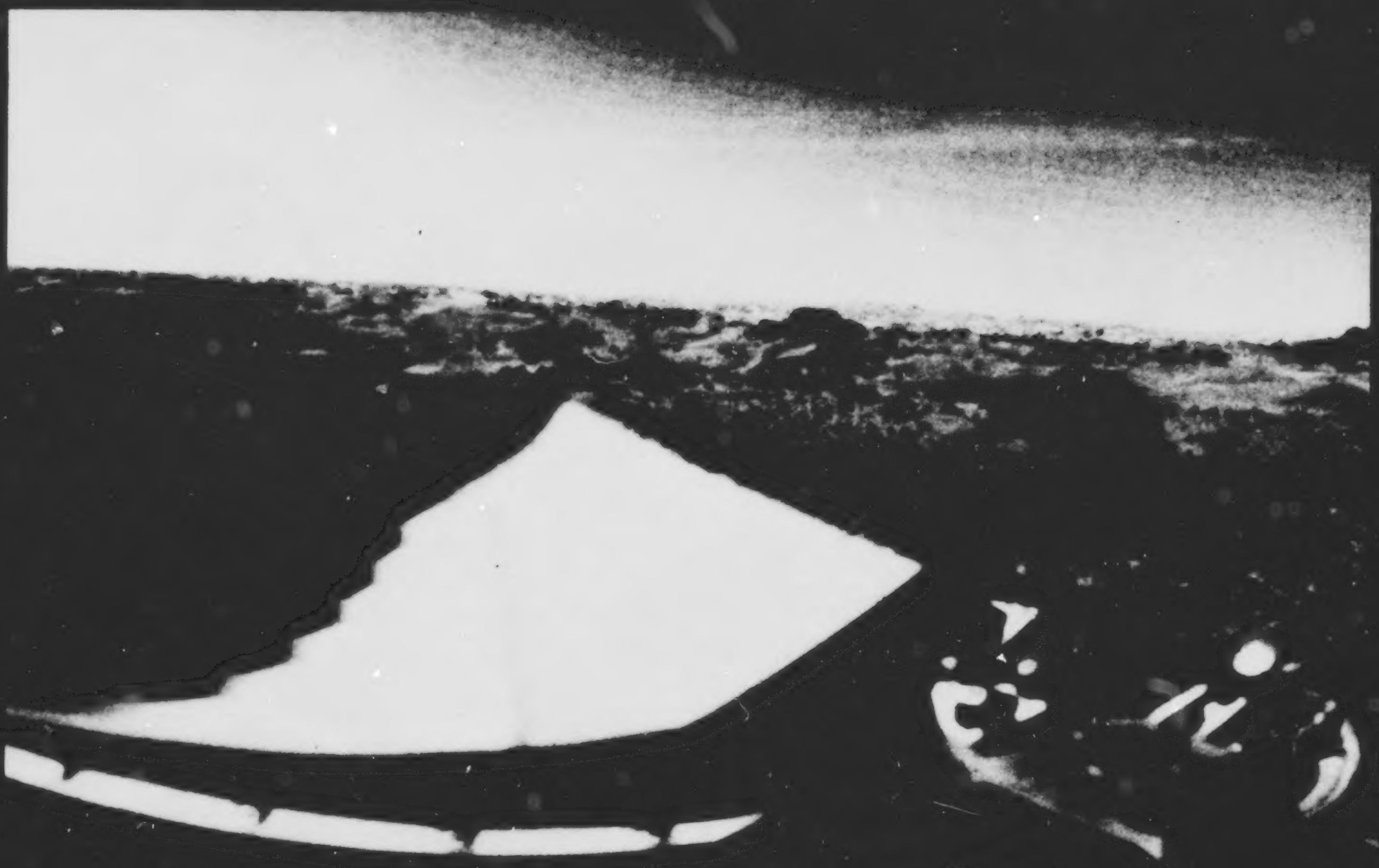

FRONT COVER

This first color photomosaic of the 48 contiguous United States was made from 569 virtually cloud-free images taken by NASA's Landsat Earth resources satellite from an altitude of 570 miles. Landsat has no cameras; its images are produced by a device known as a multispectral scanner. This system has radiation detectors which pick up visible and invisible light reflected from Earth. Equipment in the spacecraft converts light intensities to digital signals, which are sent to Earth at the rate of 15,000,000 bits per second. At ground stations, a computerized signal deciphering system translates the flow of data into images on photofilm. The resulting pictures are extremely accurate and they reveal details of Earth not attainable by conventional aerial photography. (More detailed Landsat capabilities are discussed on later pages.)

ABOVE

The Martian landscape, photographed by Viking 1 last July. The horizon is approximately two miles away and the late afternoon sun is high in the sky over the left side of the picture. In the middle third of the picture, the rocky surface is covered by thick deposits of wind-blown material, forming numerous dunes. In the center are two low hills, which may be part of the rim of a crater. The nearer of the two large rocks visible in the middleground is 10 feet in diameter and 25 feet from the spacecraft. Halfway between the horizon and the top of the picture, a cloud layer is visible. The fine-grained material near the camera contains small pits, made by the impact of discharges from the Viking Lander's rocket engines.

Spinoff 1977

AN ANNUAL REPORT

National Aeronautics &
Space Administration
Technology Utilization Office

by James J. Haggerty

TECHNOLOGY UTILIZATION PROGRAM REPORT

Acknowledgements: Todd Anuskiewicz with the assistance of James E. Beebe and Joann Kirstukas, Informatics Information Systems Co., for coordinating the preparation of this report; Charles F. Mourning, Denver Research Institute, for supplying information; William P. Taub for photography; and Rob Shultz, Plumridge Advertising.

January 1977

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foreword

The National Aeronautics & Space Administration has many missions but they can all be reduced to a common denominator: to explore Earth and its surroundings, conduct aeronautical research, and put the results to work for the benefit of mankind.

At times the benefit may be dimly perceived. Take, for instance, last year's monumental triumph of exploration, the landing of robot spacecraft on Mars. How, some ask, does probing a neighbor planet improve the lot of Earth's people?

In two ways: scientific gain and technological advancement. Though perhaps little understood, they are concrete benefits, assets as tangible as sunshine, more valuable than gold.

The Viking Mars program was undertaken primarily to learn more about the Red Planet and to gain new insight into the intriguing question of "other life" in the universe, but the primary goal was broader. It was to enlarge our knowledge of the solar system in general and Earth in particular. By fitting together more and more pieces of the cosmic jigsaw puzzle, we increase understanding of our own planet and hasten the day when man may be able to control the forces of nature to his advantage. In short, exploring the planets, and the space between and beyond them, is far more than an exercise in scientific curiosity; it is a matter of practical self-interest.

Technological advancement, on the other hand, offers equally important but more immediate returns. Technology is science applied. It is the ability of a society to make things that improve the quality of human existence. It is compounded of intellect and skill, which draw upon the scientific base to bring forth new ideas, inventions, materials and processes. It is, in a word, knowledge. It builds like an inverted pyramid, each level broader than the one before as successive generations contribute to the cumulative lore.

Technology is an important commodity of 20th Century life. It is a generator of new conveniences and improved necessities for a better way of life; it is a tool for increased productivity, hence a contributor to a nation's prosperity; it is an instrument of international prestige and an implement for helping the world's less-developed nations; and it provides a means of attacking some of mankind's most pressing problems.

Technology needs push, momentum, direction. NASA's broad quest for knowledge plays a vital role in that regard, providing stimulus and focus. Consider, for example, the enormity of the task assigned the Viking development team: to build an automated extension of human eyes, brain and arm; to send it coursing through space for almost half a billion miles to a meeting with a moving Mars; to separate two elements of the spacecraft, one to land, the other to work in orbit; to direct the operations of both, even to effect repairs, over the vast distances that separated spacecraft and controller. And to do all this not once, but twice.

Landing our robots on Mars required a technological thrust of prime magnitude. Thus, the extraordinary demands of programs like Viking, Apollo, the Space Shuttle and a variety of aeronautical research projects spur explosive innovative effort that reaches into virtually every scientific and technological discipline, creating a vast storehouse of new knowledge.

Use of that knowledge goes far beyond aerospace needs. Knowledge is readily transferable. If you build a better mousetrap, you may acquire experience in the course of the project that can be applied to a need totally unrelated to mouse-trapping.

This transfer process has been going on since the dawn of technology. In the last two decades, it has accelerated enormously, spurred by the immense flow of aerospace-stimulated technology. There have been literally thousands of spinoffs, new products and processes that owe their origins to aerospace research. Collectively, they add up to significant gain in terms of personal convenience, human welfare, industrial efficiency, and economic value.

Thus, NASA's effort produces concrete benefits in a number of ways:

- In the acquisition of a wealth of scientific knowledge, much of which will eventually find use as a base for advanced technology. It is a deferred benefit. Like oil in the ground, it is a resource for tomorrow's employment.
- In the application of space technology to do Earth jobs better, or in some cases to do jobs that cannot otherwise be done. Examples are satellite weather monitoring or the use of orbital way stations to relay global communications.
- In aeronautical research toward providing airplanes of better performance. The effort results in greater safety to those who fly and benefits everyone by improving environmental characteristics.
- In spinoff, or the secondary utilization of technology over a broad spectrum of private and public sector needs and conveniences.

This volume focuses on spinoff benefits. By way of preface, however, it is appropriate to examine some of NASA's mission-oriented programs—programs that make spinoff possible—as well as the direct benefits accruing from the principal areas of NASA endeavor: manned space flight, space science and exploration, space applications, and aeronautical research.

Edward Z. Gray

Edward Z. Gray

Assistant Administrator
Industry Affairs and Technology Utilization Office
National Aeronautics & Space Administration
January 1977

This report contains two Sections: 1. The Aerospace Harvest, and 2. Technology Twice Used. There is also an appendix, TU at Work. Section 1 describes a number of NASA's ongoing research programs that promise future benefits of a **direct** *nature. The final chapter of that Section illustrates how transfer of NASA technology normally occurs. Section 2 describes many examples of* **indirect** *benefits resulting from the use of NASA technology, a number of which were brought about by programs of the Technology Utilization Office that have as their purpose the practical application of aerospace technology. The appendix briefly describes the major activities of the Technology Utilization Office, and it identifies regional NASA officials and contractor personnel who can be contacted by those in need of NASA technical information or assistance. Or, if preferred, inquiries may be addressed to:*

Director, Technology Utilization Office
P.O. Box 8756
Baltimore-Washington International Airport
Maryland 21240

Spinoff 1977

an annual report

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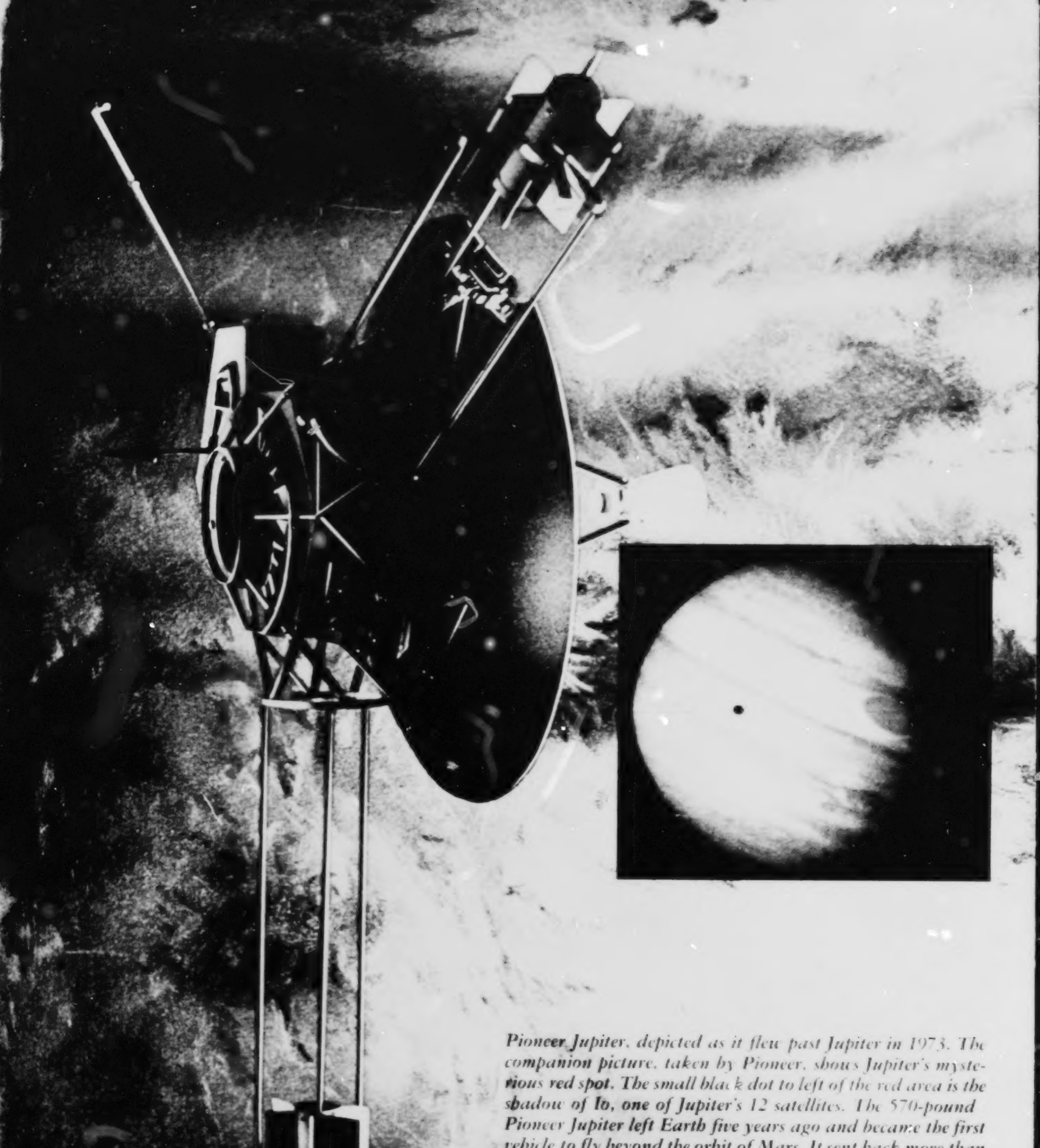
The Aerospace Harvest

Space exploration and aeronautical research are paying dividends in direct benefits and in spinoff, the secondary use of aerospace technology.



Pioneer Jupiter, depicted as it flew past Jupiter in 1973. The companion picture, taken by Pioneer, shows Jupiter's mysterious ***red spot.*** *The small black dot to left of the red area is the shadow of* ***Io, one*** *of Jupiter's 12 satellites. The 570-pound Pioneer Jupiter left Earth five years ago and became the first vehicle to fly beyond the orbit of Mars. It sent back more than 300 photos of Jupiter and the planet's inner moons, then continued onward past the orbit of Saturn. Now more than a billion miles from Earth. Pioneer Jupiter will reach the orbit of Uranus—two billion miles from home—in 1979. Eventually it will become the first man-made object to escape the* [illegible]

Study of the solar system and the space beyond provides new perspective on Earth's place in the universe.

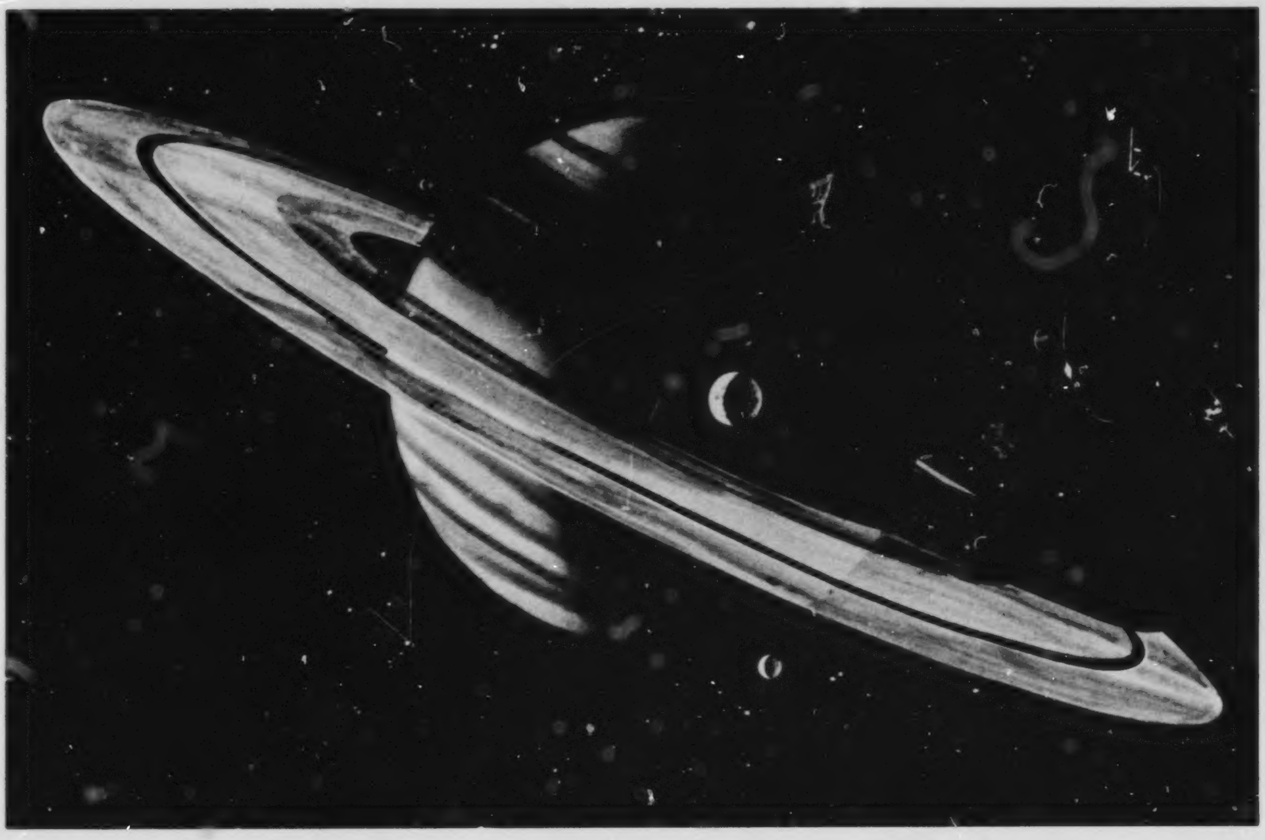
space science and exploration

More than a billion miles from Earth, a tiny speck in the vast void of space, Pioneer Jupiter flies on. It left the home planet five years ago, never to return. In 1973, the little spacecraft completed its primary mission, passing near the planet Jupiter and sending back photos and data. Then it continued onward. Ten years hence it will escape the solar system, the first manmade object to do so.

A year behind is a companion craft, Pioneer Saturn, which will reach the orbit of the great ringed planet in 1979.

These two interplanetary probes, along with the Viking Mars spacecraft, point up the extraordinary scientific reach man has attained in his efforts to uncover the mysteries of the universe. They are part

A companion to Pioneer Jupiter, Pioneer Saturn is flying a different route through far-distant space. Launched a year after its predecessor, Pioneer Saturn made the closest approach to Jupiter—29,000 miles—in 1974. It is scheduled to arrive at Saturn in 1979.

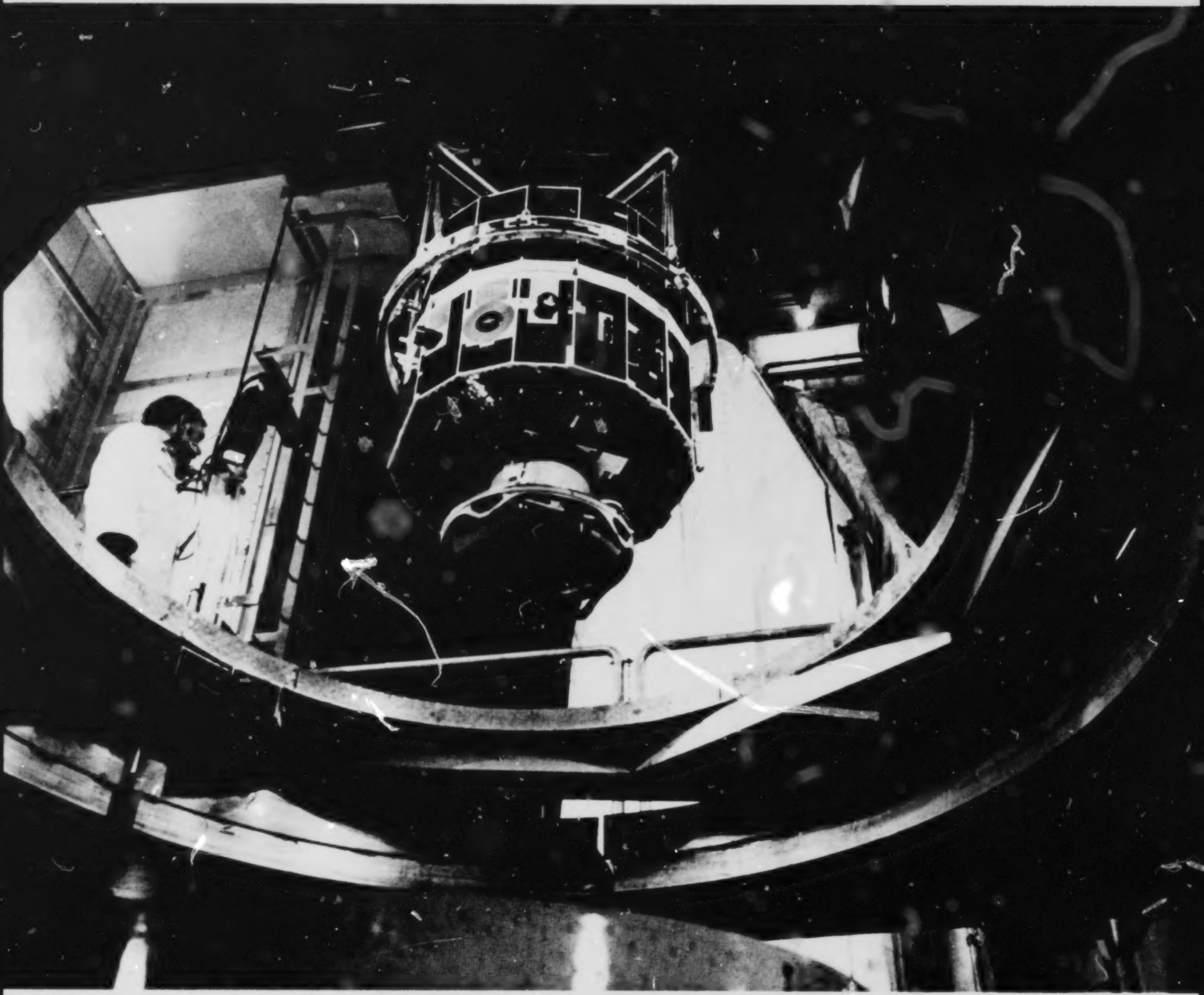


The Red Planet Mars, as photographed by the Viking spacecraft last year. The most ambitious automated exploration ever attempted, the Viking project was highly successful. Two Viking Orbiters and two Mars Landers teamed in a comprehensive study of extraterrestrial life signs, the Martian atmosphere and the planet's geology.

of NASA's broad space science program, which employs deep space probes like the Pioneers, planetary landers like Viking, Earth-orbiting satellites, nonorbiting sounding rockets, aircraft, balloons, and Earth-based telescopes in a sweeping study of space phenomena.

NASA has launched more than 300 spacecraft into Earth orbit or into deep space trajectories. In addition to the landings on Mars, our spaceships have flown by Mercury, Venus, and Jupiter—returning data that provides greater understanding of those planets; they have mapped the highly complex magnetosphere that extends many thousands of miles from Earth; they have reported on the effects of solar radiation on Earth's ionosphere and its atmosphere; they have studied the Moon, the Sun, and the solar wind; and they have looked far into space, acquiring information on ultraviolet, infrared, X-ray and gamma-ray radiations that tell us more about the stars and the galaxies. In less than two decades, man probably has learned as much about the universe and his place in it as in all the prior years of history.

The Martian surface appears almost black in this computer enhanced image of a Martian sunset. The most prominent feature in the foreground is a silhouette of the top of one of Viking's power system covers (far right). The sky appears white near the sun position, and the blue to red color variation is explained by a combination of scattering and absorption of sunlight by atmospheric particles.



Explorer 54 is one of several NASA Atmosphere Explorer spacecraft which study the chemical processes and energy transfer mechanisms that control the behavior of Earth's atmosphere and ionosphere. Operating at relatively low altitudes—less than 100 miles above Earth—the Atmosphere Explorers have propulsion systems which allow changes of orbit for broader data acquisition.

New Science Programs

Yet, the job is just beginning. Exploring the incredibly complex workings of the solar system and the space beyond is a monumental task which, like the universe, has no apparent end. But earlier work has provided a solid base for continuing expansion of scientific knowledge, and advancing technology is making available ever more sophisticated spacecraft and instrumentation. NASA's space science program is far too broad for complete detailing, but a representative sampling of scheduled and contemplated projects includes: continuing study, by Earth-orbiting satellites, of the Earth, the Sun and deep space phenomena; a moon-orbiting spacecraft to survey

NASA is conducting a continuing program of sun study with its family of Orbiting Solar Observatories. Eight OSO spacecraft, ranging in size from 600 pounds to more than a ton, have been sent into space over the past 15 years. Largest and most recent of the series is OSO-8, launched in 1975 to seek high resolution sun data and to search for celestial radiation sources.

lunar chemical and physical properties; missions to Venus, Jupiter and Mars; and manned experiments in space made possible by the advent of the Space Shuttle in the 1980's.

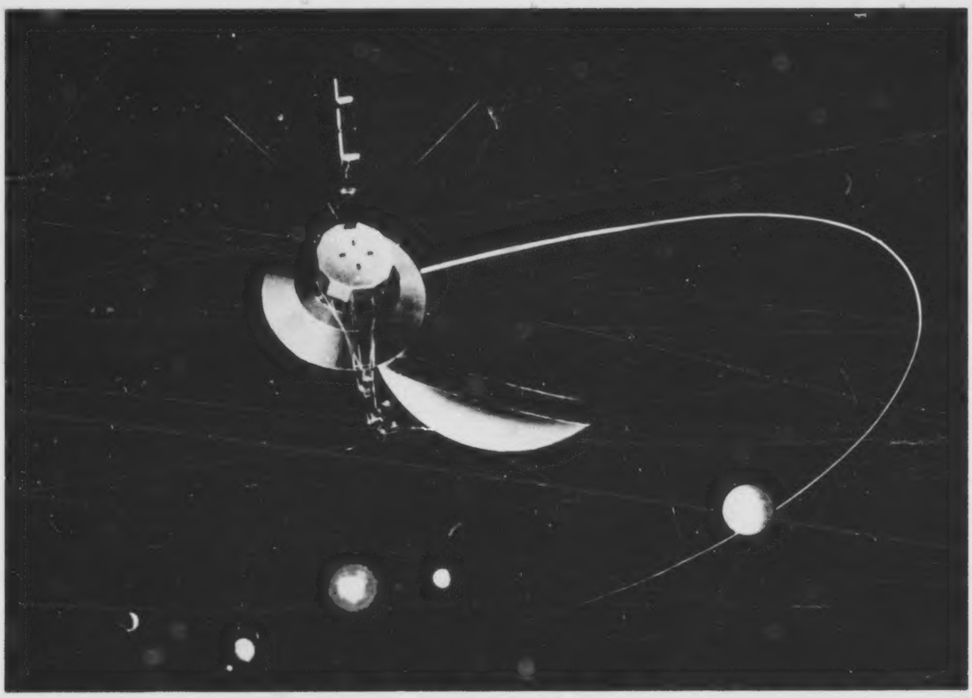
Expanding Earth Knowledge

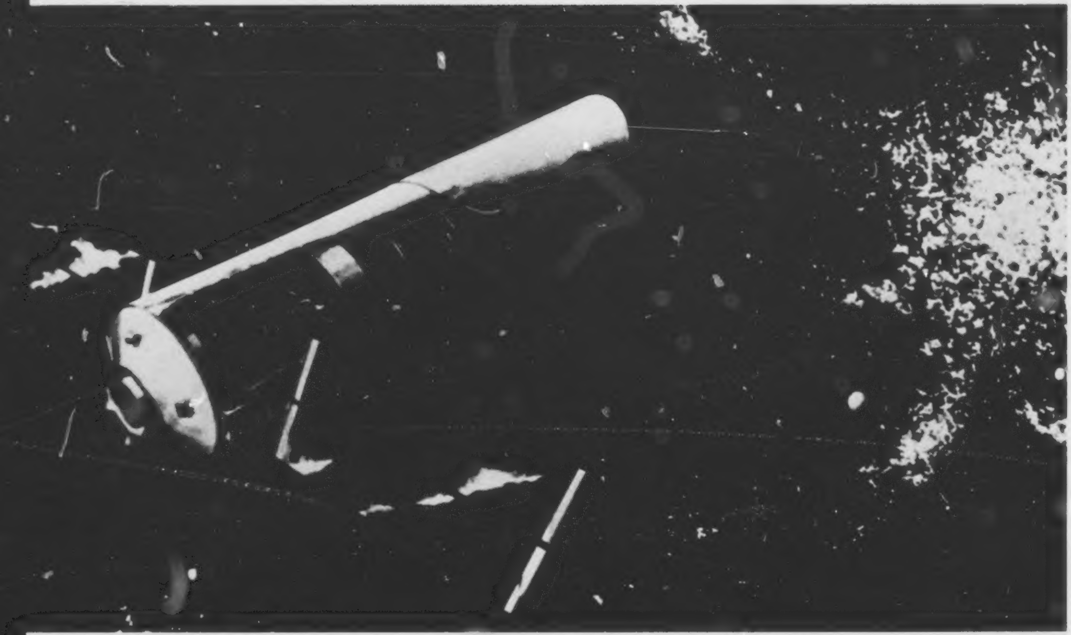
With these and other spacecraft, NASA scientists will add millions of new tiles—each tile a bit of knowledge—to the rapidly growing mosaic that is our picture of the universe. This wealth of scientific information is a primary benefit of the space program. All of these investigations of mysterious other worlds tell us more and more about Earth.

Exploration of space has practical implications for terrestrial sciences such as meteorology, geology, and biology. For the first time in history these sciences can be compared with conditions elsewhere.

Such comparison begets a new perspective. Comparative study of the whole solar system offers better insight into Earth's own complex workings. With better understanding of the forces that control

An artist's concept of an unmanner Mariner spacecraft as it passes by Saturn in 1981. Two Mariner Jupiter/Saturn spacecraft will be launched this year to fly by Jupiter in 1979 en route to Saturn. The Mariners will send data and pictures of the planets, their satellites and Saturn's rings for comparison studies of the two planetary systems.

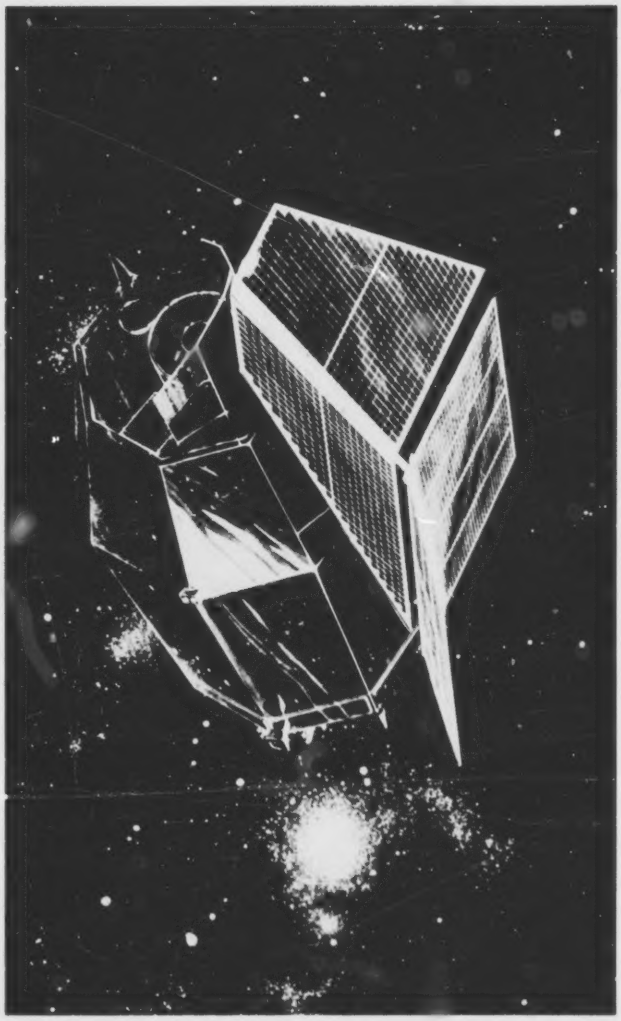




A scientifically exciting unmanned facility is NASA's Large Space Telescope, scheduled for operational use in the 1980s, which will allow observations deeper into space and with greater detail than has heretofore been possible. To be delivered to orbit by the Space Shuttle, the telescope will operate at an altitude of approximately 380 miles, far above the layer of Earth atmosphere that distorts ground-based observations.

the Earth comes the possibility of managing these forces to humanity's advantage. Comparative knowledge of planetary meterology, for instance, might lead to weather control on Earth. Greater information about solar system geology could make possible precise earthquake prediction. Discoveries about the development of living organisms— or even their lack of development—elsewhere in the universe might spark biological breakthroughs of tremendous significance. Or, when enough tiles of the cosmic mosaic have been fitted together, there may come vast benefit totally unimaginable today.

In short, today's science is tomorrow's application. Meanwhile, there is practical value in the development of an incalculably valuable resource—knowledge, the greatest legacy one generation can pass to another.



First of a series of High Energy Astronomy Observatories is slated for launch this year. Two additional observatories will go aloft in 1978 and 1979. Equipped with more sensitive instruments than were previously available, these three-ton spacecraft will provide increased understanding of deep space phenomena.

NASA's Shuttle Orbiter heralds a new era of broader space capability and greater beneficial impact.

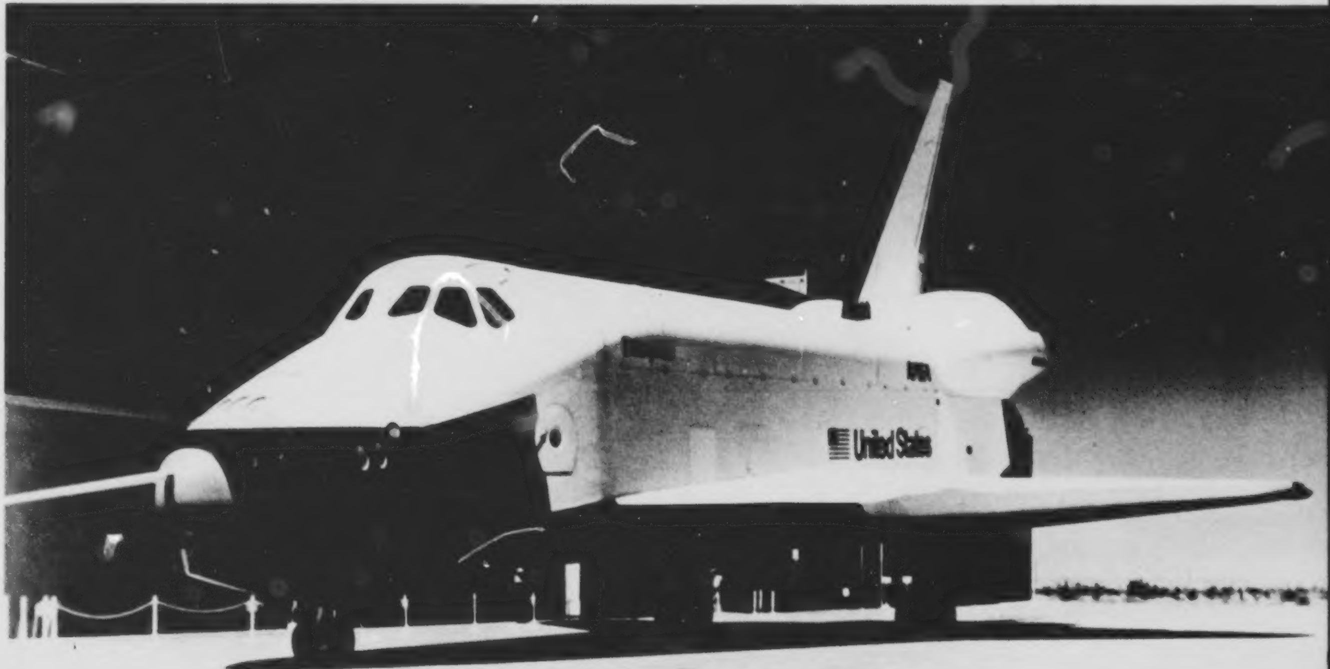
shuttling to orbit

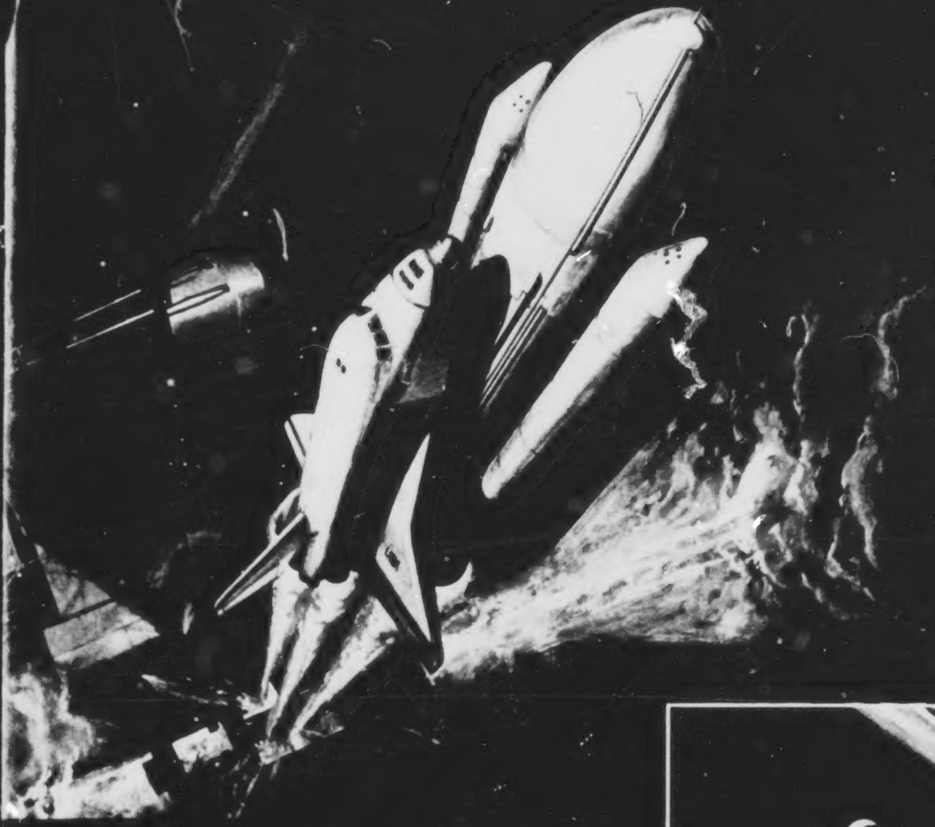
This year there will be a new shape in the skies over California, a spacecraft that looks like a heavyset jetliner and lands like one. It is NASA's Shuttle Orbiter, harbinger of a new dimension in space capability that will begin in 1980.

The Orbiter is the manned portion of the Space Shuttle Transportation System, a reusable Earth-to-orbit workhorse that will usher in an era of ready access to space with attendant advantages in cost, flexibility, and breadth of space operations.

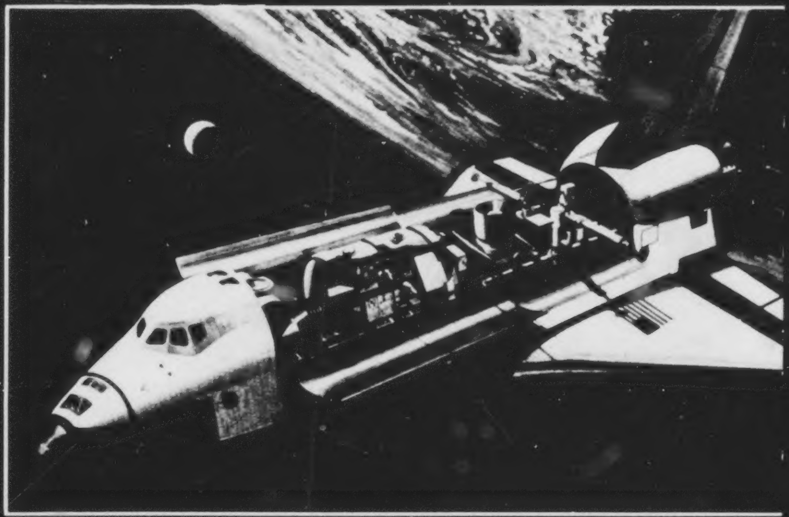
A cargo and personnel carrier, the Shuttle will deliver payloads to orbit, eliminating the need for costly launch vehicles. It will extend the useful life of satellites by allowing repairs in orbit or retrieval of the satellite for refurbishing on Earth. It will lift to orbit upper stages that can boost satellites to higher altitudes or launch probes into deep space trajectories. It will permit scientists to study and experiment at vantage points as high as 500 miles above Earth. It opens the door to building large structures in space. It will pave the way for manufacture in space of certain items, such as pharmaceuticals and

The Space Shuttle Orbiter begins flight tests this year. In initial tests, the manned Orbiter will be carried piggyback to high altitude by a Boeing 747 and released to glide to a landing at NASA's Dryden Flight Research Center, California.

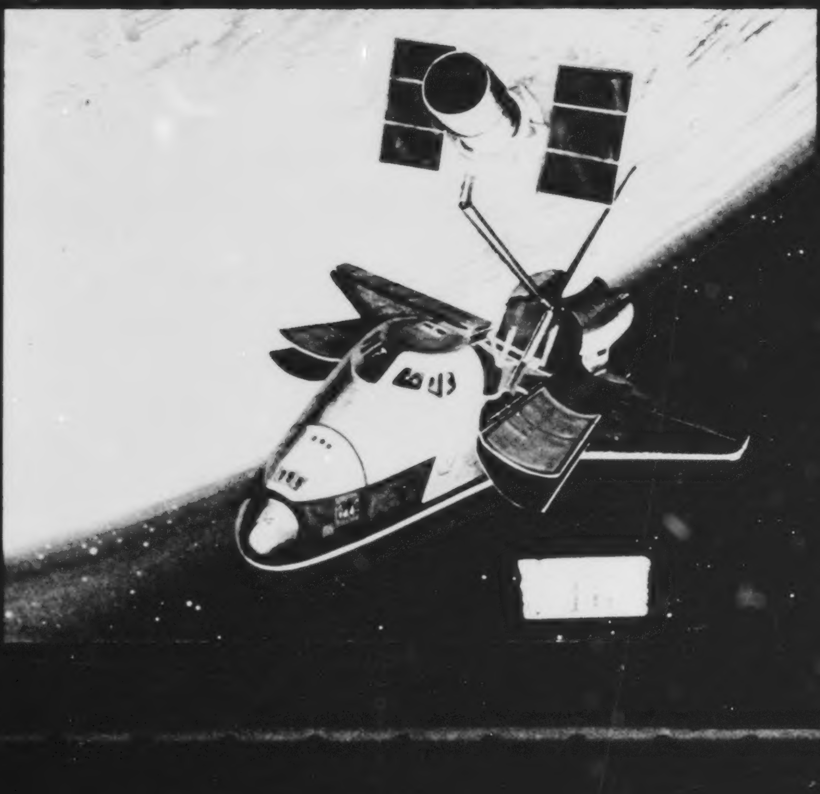




This artist's concept shows the reusable Space Shuttle at blast-off. The Shuttle is boosted to orbit by the combined 6,800,000 pounds thrust produced by the Orbiter's three main engines and two large solid rockets. The Orbiter's engines draw their fuel from the large propellant tank, which is dropped off just before the airplane-like Orbiter is inserted into orbit. The solid rockets, jettisoned at about 100,000 feet altitude, descend by parachute to an ocean landing for recovery and reuse.



Spacelab, a flying laboratory that fits into the Shuttle Orbiter's payload bay, makes possible manned experiments in space for periods of seven to 30 days. Telescopes and other instruments in the aft section of the bay are remotely operated from the pressurized manned module in the forward section. First Spacelab flights are planned for 1980.



An important feature of the Space Shuttle is its ability to retrieve unmanned satellities for repair in orbit or return to Earth for refurbishing. In photo, a robot arm operated by crew members on the Orbiter's flight deck is maneuvered into position to "capture" a satellite. Retrieval and reuse of costly satellites offers large-scale savings.

crystals for electronics, which are better produced in the vacuum or weightless environment.

These capabilities give NASA repeated opportunities to exploit the full potential of space operations. Reusable Orbiters, boosters and satellites mean substantially reduced costs, an estimated billion dollars a year. The savings can be translated into additional payloads to meet predicted needs for more Earth-oriented applications—advanced weather forecasts, communications, Earth resources, and other benefits.

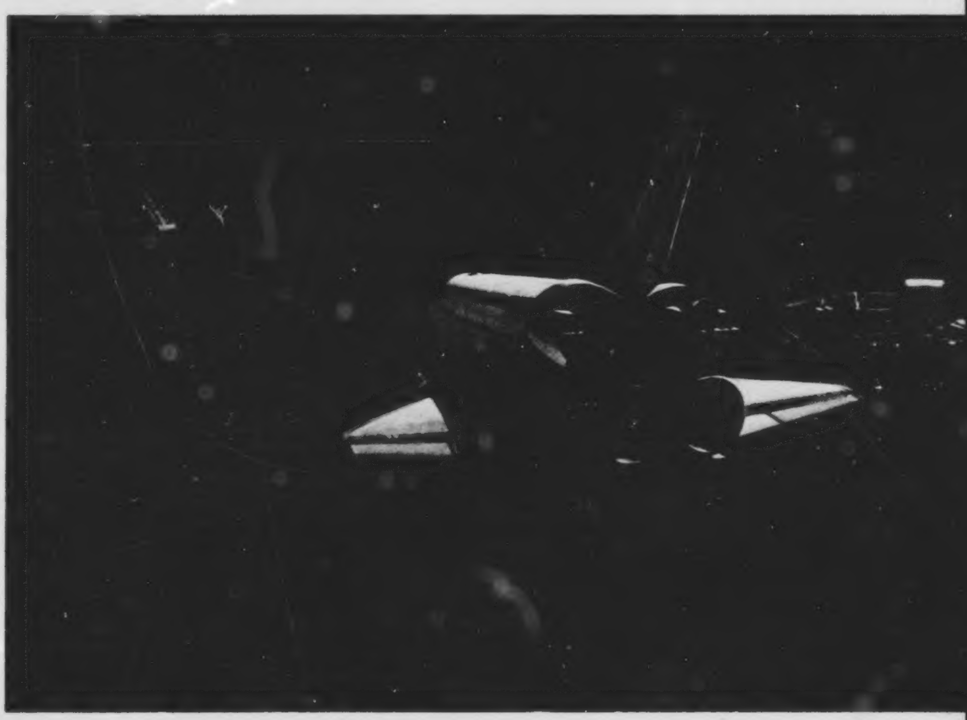
The Space Shuttle, being developed under the direction of NASA's Johnson Space Center, Houston, offers a particular capability for scientific investigations and Earth-oriented studies, because it allows whole teams of experimenters to go into space. In the Spacelab—a pressurized module that fits into Orbiter's cargo bay—scientists can work in shirt-sleeve environment for up to 30 days. Spacelab thus offers a platform from which Earth can be examined as a whole. It allows astronomical observation unobscured by Earth's atmosphere and it permits a new range of human-directed experiments under long-term gravity-free conditions.

Spacelab is an international program under the aegis of the European Space Agency. Nations participating in design and development of the orbital laboratory include Austria, Belgium, Denmark, France, Ireland, Italy, the Netherlands, Spain, Switzerland, the United Kingdom, and West Germany. NASA's Marshall Space Flight Center, Huntsville, Alabama, coordinates activities of the European group.

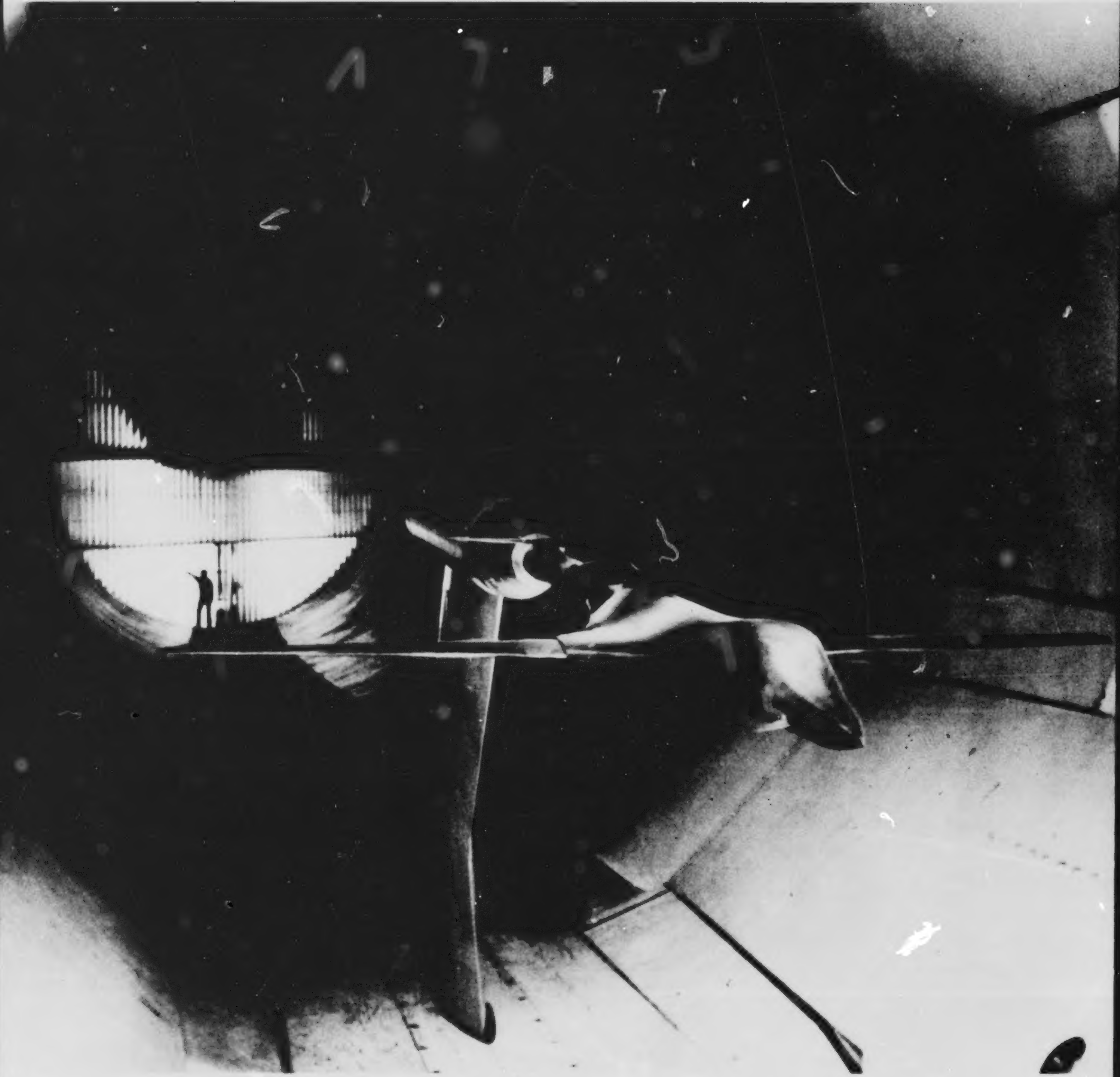
Launched like a rocket, the Shuttle operates in orbit as a maneuverable spacecraft and returns to Earth landing like an airplane at shuttle-ports in California and Florida. Launch power is supplied by two large solid-rocket boosters and by the Orbiter's three main engines, which draw fuel from a huge external tank. The solid rockets are recoverable for reuse; the big tank is jettisoned after it has served its purpose.

This year, the Orbiter will be tested as an atmospheric vehicle at Dryden Flight Research Center in California. Mounted piggyback atop a modified Boeing 747 jetliner, the Orbiter will be carried to altitude and then released in a series of unpowered flights to check out aerodynamic and flight-control characteristics. It will glide to landings at the Mojave Desert test center.

The first manned *orbital* test of the Space Shuttle is targeted for early 1979. After six such development flights, the new era of expanded capability will begin with the first operational mission in mid-1980.



At the conclusion of a mission, the Orbiter re-enters the atmosphere and lands like an airplane. The Orbiter is then inspected, serviced, fitted with new payloads, mated with its solid rockets and fuel tank, and moved to the launch pad for another trip into space. Turn-around time is two weeks.



In photo, an airplane model is undergoing tests in a transonic wind tunnel as part of a NASA program to reduce aircraft fuel consumption. NASA is exploring a variety of wing shapes designed to change the build-up of air resistance at high subsonic speeds. These design measures allow an aircraft to fly faster or further without increased fuel consumption.

18

NASA aeronautical research aims at providing the technology for new airplanes that will be safer, quieter, more energy efficient, and have less impact on the environment.

the shape of wings to come

You pay more for your airline ticket today because jet fuel prices have soared into the stratosphere—and they are still climbing. You doubtless would welcome a less fuel-thirsty jetliner. So would the airlines. Rising fuel costs have had a major impact on their finances in recent years.

NASA is already engaged in a concentrated effort to reduce airplane fuel appetites. The Aircraft Energy Efficiency program is part of NASA's broad research activity aimed at improving performance of all types of aircraft. Aeronautical researchers have identified technologies which collectively could cut fuel consumption in half—a potential of enormous economic significance.

Fuel-saving research is not a quest for a single, giant breakthrough; rather it is an effort to advance technology in several key areas that influence consumption. The technology being developed offers added value in passenger safety and comfort, noise reduction, and less engine-exhaust emissions.

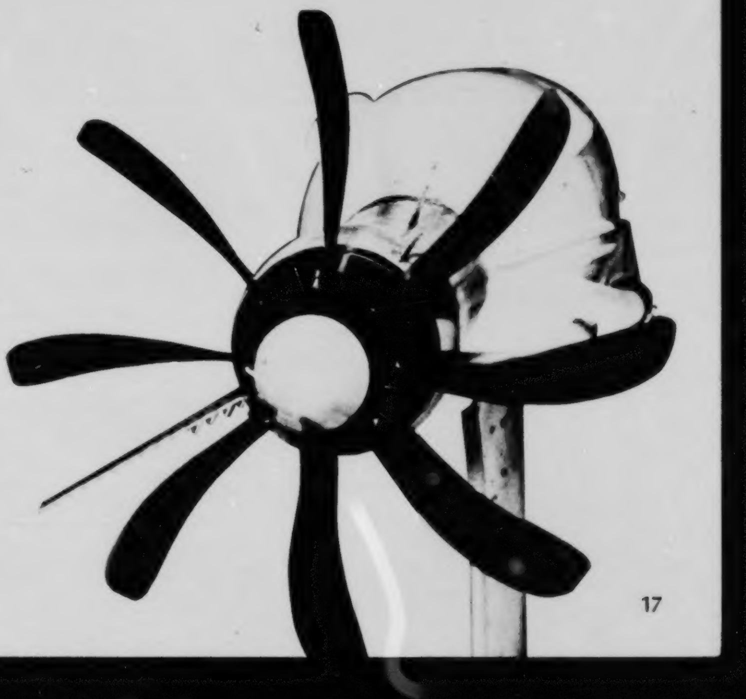
Engine Research

Aircraft engines deteriorate with use and age just as auto engines do. Worn parts induce fuel waste. NASA's Lewis Research Center is trying to determine the major causes of component deterioration; for example, which worn parts waste the greatest amounts of fuel, and how to extend the period of maximum effectiveness of these parts. From this research, it is expected that improved components—expected to be available by 1980—will lead to a five percent decrease in engine fuel consumption.

Another approach to fuel efficiency is mechanical mixing of the two separate engine air streams. Mixing produces more uniform exit velocities and temperatures, and that translates into lower fuel consumption and less noise. This system, too, may be available by 1980.

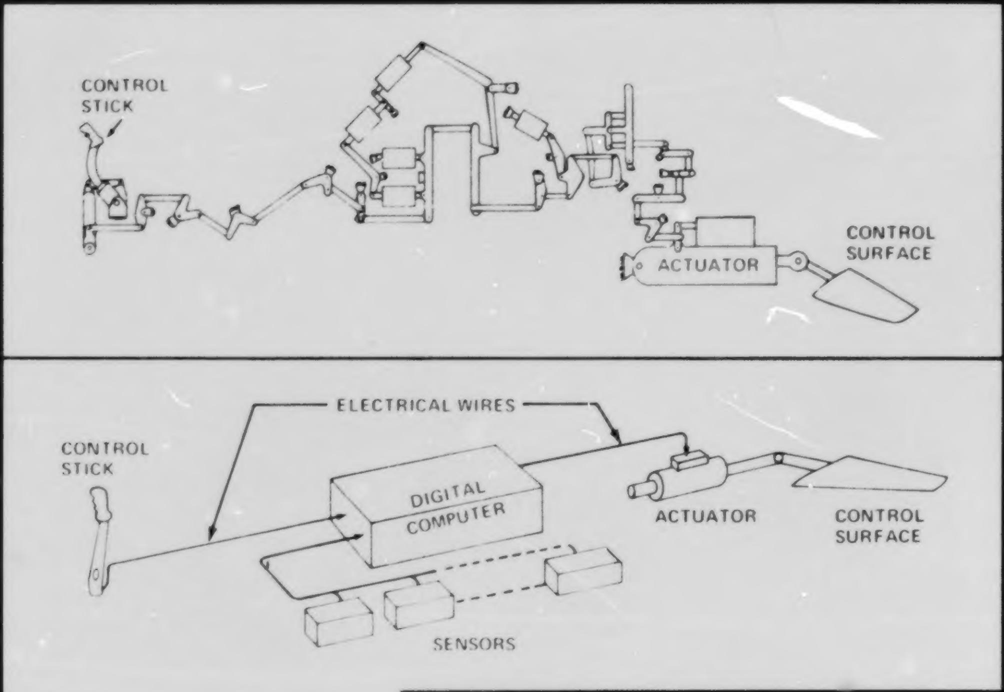
Looking further ahead, NASA is performing research which could lead to an advanced fuel-saving engine incorporating the following improvements plus other important advances. The engine would operate at higher temperatures and pressures, which means greater fuel efficiency. Its many components would be lighter, reducing overall engine weight. It also might have a "regenerative" system which recycles heat for additional thrust. The advanced engine, which could be in service by 1990, will offer a 10 percent reduction in fuel use.

NASA researchers are also reinventing the propeller. It was once thought that the propeller had reached its limit with airplane speeds on the order of 400 miles per hour, the limiting factor being the



As part of the aircraft fuel efficiency research program, NASA is taking a second look at the propeller. The turbine-driven propeller has inherently better fuel consumption than the jet engine, but limitations of propeller tip speed and its vibration and cabin noise characteristics brought about its decline in commercial airplane use. New research indicates that redesign of propeller shapes offers considerably higher tip speeds; also structures and acoustics advances can alleviate the vibration and noise problems. Tests have shown that this propeller with "swept tips" can operate efficiently, smoothly and quietly at jetliner speeds and altitudes with substantially better fuel economy.

ELECTRONIC VS. MECHANICAL CONTROL SYSTEMS



Fuel consumption and airplane stability can be improved by a new Digital Fly-By-Wire control system being tested in this airplane at NASA's Dryden Flight Research Center. The system employs motion sensors, electric wiring and on-board computers to control the airplane, instead of the conventional weighty complex of rods and linkages (see diagrammed comparison). Computer control permits a smoother flight, lighter aircraft structures and smaller tail surfaces. Multiple weight savings cut fuel consumption.

speed of the propeller's tip. However, a second look at the propeller indicates that tip speeds can be increased considerably. Tests show that a turbine driven, eight-bladed propeller with "swept tips" can achieve high efficiencies at the speeds and altitudes at which jetliners fly. Turboprop engines inherently offer better fuel economy than jets, and the propeller's comeback may allow fuel savings of 20 percent.

Flying by Wire

Dryden Flight Research Center is flight-testing an airplane which incorporates a new control system that contributes to fuel economy. Called the Digital Fly-by-Wire System, it employs motion sensors, electrical wires, and on-board computers instead of the conventional weighty complex of rods and linkages that normally drive control surfaces. The fast-reacting, computer-controlled electronic system provides the exact amount of control response for more stable flight. To the passenger, this system means a smoother, safer ride—it softens the bumps and sways caused by turbulent air. To the designer, it offers broad new latitude: the extra stability and precise load distribution assured by computer control allow use of lighter structures and smaller tail surfaces, reducing airplane weight and further cutting fuel consumption.

None of these advanced concepts is a way-out, "someday" type of thing. Supercritical wings, the fly-by-wire system, and composite materials are already in flight-test status. Some will enter airline service gradually, being incorporated into existing jetliners.

Others, needing further research, will appear in the next generation of aircraft a decade hence. They suggest that the commercial airliner of 1990 will differ considerably in appearance from today's aircraft and offer marked improvements in overall efficiency.

General Aviation Research

The NASA aeronautics program is giving increasing attention to "general aviation," the term used to describe civilian aircraft that are not commercial airliners. These planes, which number about 140,000 domestically and fly more mileage than airline transports, range from single-seat craft to multi-passenger business jets. NASA's effort seeks new technology to improve performance, safety, fuel consumption, and noise characteristics.

Examples of safety research include full-scale crash tests aimed at providing better protection for general aviation pilots and passengers in the event of an accident. And it includes work toward preventing stalls and spins, which account for about 35 percent of general aviation fatalities.

NASA is also developing a family of general aviation wings for more efficient flight and lower fuel consumption; investigating a low-cost computerized stability and control system; studying methods of acoustic treatment of engines and propellers to reduce noise; applying noise and emission-reducing techniques to the small turbofan engines used by business jets, and looking into ways of improving spray accuracy of agricultural aircraft.

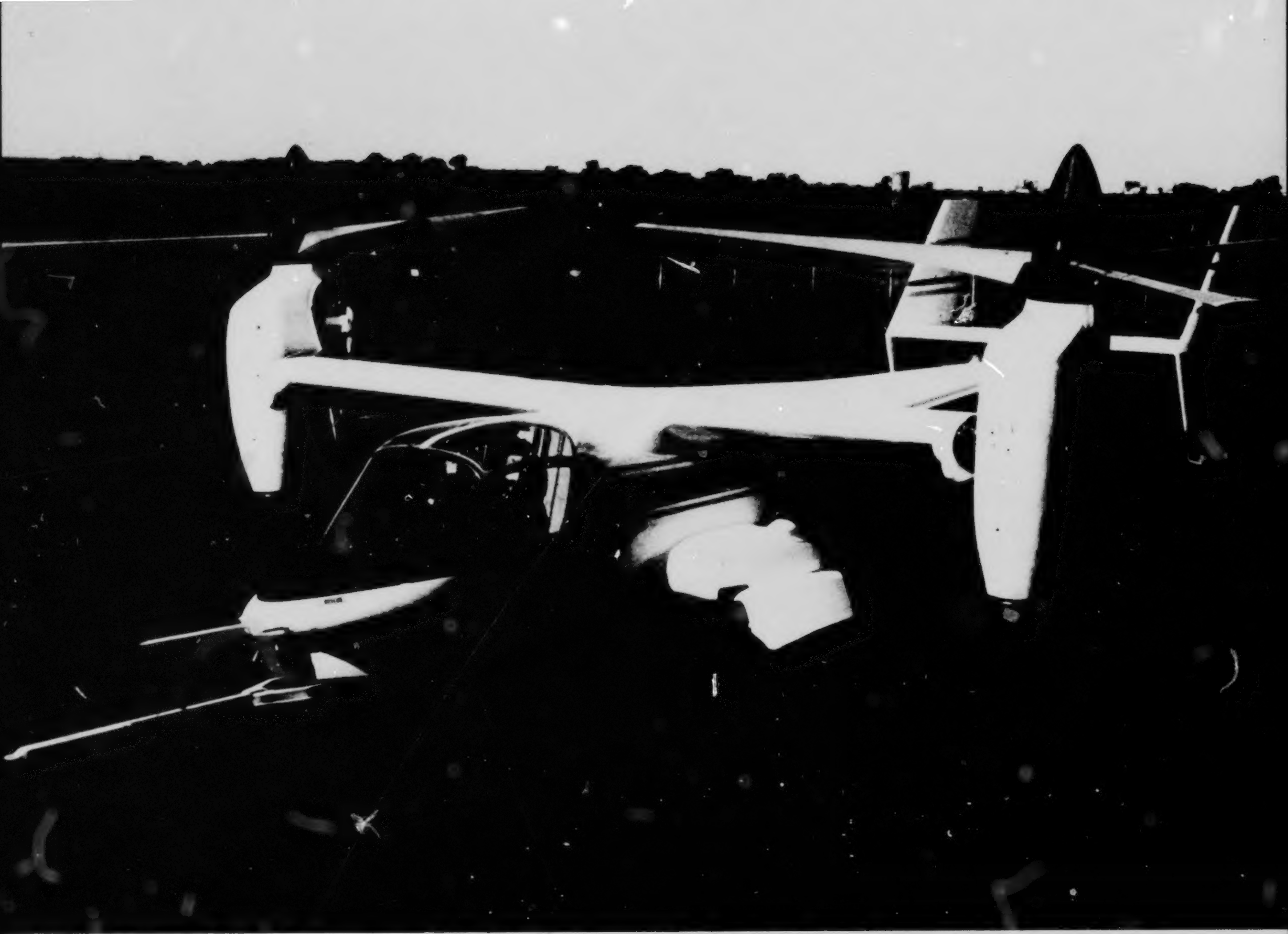
Reshaping the Wing

Improved aerodynamics reduces air resistance, saving fuel because the engine does not have to work as hard. An important advance developed by NASA's Langley Research Center is the "supercritical" wing—actually a family of new wings for various types of aircraft. The wing airfoil has a different shape: it is flattened on top and the trailing edge curves downward. These design features delay the build-up of air drag at high subsonic speeds, allowing the plane to fly faster or farther without increased fuel consumption.

The novel airfoil permits use of an entirely new wing shape, because it can be made as much as 50 percent thicker without losing high-speed efficiency. Thickness makes it possible to increase the wing span, which in turn increases lift and reduces fuel consumption. So future airliners may have wings more like those of sailplanes, allowing the plane to fly 15 percent farther with the same fuel load.

A companion effort seeks to smooth the layer of air next to the airplane's skin—the "boundary layer," it is called. Normally this air is turbulent, creating drag and wasting fuel. The "laminar flow" concept—laminar, for smooth—calls for removing

Full-scale airplanes are being deliberately crashed in a joint NASA/Federal Aviation Administration program that addresses safety in general aviation aircraft, meaning all civil planes except commercial airliners. Aim of the program is to provide greater protection for pilots and passengers through improved aircraft structural design.



The NASA/Army Tilt Rotor Research Aircraft has large helicopter-like rotors for takeoff and landing, but in cruise flight the rotors tilt forward to become propellers. The craft can cruise at about 460 miles per hour, yet it retains the helicopter's vertical take off and landing and hovering characteristics. It is considered a promising concept for short-haul commercial transportation.

the turbulent air by suction, drawing it through porous aircraft surfaces by lightweight pumps. Smoothing the boundary layer affords fuel savings estimated at 20 to 40 percent.

Obviously, a lighter airplane also eases the engine's workload. Weight-trimming research focuses on new composite materials. These are graphite or boron fibers woven into a matrix of resin or aluminum. Composites not only are lighter than the materials they would replace—they also are stronger. They can reduce jetliner weight as much as 25 percent and cut fuel consumption accordingly.

Rotor Research

With an eye toward improving the capabilities of the versatile helicopter, NASA and the U.S. Army are jointly flying a unique helicopter test bed at Langley Research Center. Built by Sikorsky Aircraft, the two Rotor Systems Research Aircraft (RSRA) will permit rotor tests over a wide range of altitudes and speeds up to 300 knots. The RSRA will reduce costs and the time-consuming trial-and-error experimentation now involved in the development of rotorcraft.

This test system has a special capability—it can be flown as a conventional helicopter or as a compound helicopter, a winged vehicle which offers greater cruise speed while retaining its vertical flight characteristics. The conversion is accomplished by adding two auxiliary turbofan engines and a 45-foot wing.

The RSRA is a flying laboratory. Instruments that measure flight loads are built into the fuselage and the main rotor support structure contains devices to measure the forces acting upon the rotor during flight, just as is done in a wind tunnel. Similar

The design of this Beech trainer was based on NASA's General Aviation Wing-1, which made possible construction of a smaller, lighter airplane with greater lifting capacity. NASA is developing a family of airfoils to improve flight performance of general aviation aircraft.

This conventional-looking helicopter is actually a flying laboratory called the Rotor Systems Research Aircraft. Jointly developed by NASA and the U.S. Army, it is heavily instrumented, can accommodate a variety of different rotor systems, and can be fitted with wings for test as a compound helicopter, a hybrid 'copter-airplane.

instrumentation is incorporated in the wing, tail rotor and auxiliary engines. The RSRA will serve as a standardized base for comparing various systems by allowing tests of different rotors on the same aircraft and under the same conditions. Data acquired by the two flying laboratories will help develop technology to increase helicopter performance, safety, strength and reliability, and to reduce noise, vibration, and maintenance requirements.

Another VTOL (Vertical Take-Off and Landing) project, again a joint NASA/Army effort, is the Tilt Rotor Research Aircraft. This vehicle has large rotors like those of a helicopter for vertical take off and landing. Once airborne, the rotors tilt forward to become propellers for moderately high-speed cruise flight—about 460 miles per hour. Thus, the tilt rotor concept combines a helicopter's take off and landing characteristics with the greater speed and range of a turboprop airplane. This hybrid aircraft shows considerable promise for short-haul commercial transportation—for instance, as an intercity air ferry to large jetports.

In other avenues of research, NASA is probing a wide spectrum of aviation needs and problems. Research on supersonic cruise aircraft is aimed at solving environmental and efficiency problems that limit the usefulness and acceptability of current supersonic aircraft. Other programs include cooperation with the Federal Aviation Administration in development of a system to prevent mid-air collisions; investigating the use of lasers to warn pilots of clear air turbulence ahead of the aircraft; and redesigning landing gears to reduce "slush drag"—the retarding influence of runway snow and slush—which can keep a plane from reaching flying speed. In these and a broad range of related projects too numerous to mention, NASA's aeronautical research is providing direct benefits to airline travelers, operators, manufacturers, and shippers.

Villagers in India watch a television program beamed by NASA's ATS-6 spacecraft in a 1976 demonstration of how direct broadcasting can provide important benefits to developing nations whose communications systems are primitive. Direct broadcast satellites like ATS-6 have extremely powerful transmitters, obviating need for the elaborate ground receiving system associated with commercial communications satellites. In the NASA/India experiment, TV programming was made available to 2,400 remote villages which have no television stations; small, inexpensive antennas were able to pick up the strong transmissions from ATS-6.

Students at a Three Forks, Montana junior high school are shown participating in the Health Education Telecommunications (HET) demonstration. Live interaction via ATS-6 satellite was an integral part of each day's lesson. Several schools in the Rocky Mountain area continue to use the career education programs which were recorded for future use.

A significant part of NASA's effort is aimed toward direct public benefit from space and surface systems.

technology for societal needs

Last year some five million people in rural India watched daily television—which is extraordinary because India has no nationwide TV system.

In an exciting and far-reaching demonstration known as SITE (Satellite Instruction Television Experiment), TV programs were beamed to 2,400 remote villages by NASA's Applications Technology Satellite-6. The ATS-6 uses "direct broadcasting," sending its signals directly to simple, low-cost ground antennas by means of powerful on-board transmitting equipment. This unique capability eliminates the need for an elaborate and expensive ground complex of stations, antennas, amplifiers, and land lines. Direct broadcasting opens up a world of opportunity to developing nations, affording a means of providing group instruction and entertainment in outlying areas where communications are either primitive or non-existent.

For the Indian experiment, the ATS-6 was maneuvered into orbit over Lake Victoria in East Africa, where the satellite could "see" all of India. From the cities of Delhi, Ahmedabad and Amritsar, the Indian government transmitted specially prepared television programs to ATS-6, which rebroadcast them to the villages. Each village was provided a 23-inch TV set for community viewing and an inexpensive aluminum dish antenna to pick up the signals.

The community set was used for an hour and a half each morning as a teaching aid for children. In the evening, adults—many of whom had never heard of TV—turned out in large numbers for two and a half hour sessions divided equally between entertainment and practical instruction. A typical evening show included short features such as "Festivals and Fairs" and "Folk Music from Elsewhere," together with adult education discussions of nutrition, hygiene, and family planning. The top-rated shows, which had audiences begging for reruns, were those on pest control and how to increase crop yield. SITE was an outstanding success, acclaimed by villagers and government officials alike.

India's problem of inadequate communications is shared by many developing nations. When the year-long SITE experiment was concluded last August, ATS-6 conducted similar demonstrations in some 30 African countries over a three-month period, showing how satellite communications can quicken the pace of national development by improving commerce and education. Then ATS-6 was maneuvered back to the Western Hemisphere —over Ecuador—for a new series of experiments, including direct broadcasting to Latin America.

You might think that the communications problem does not apply in highly developed North America. It does, though—in places like Alaska, northern Canada, the Rocky Mountains, and Appalachia. In these and other areas, Earth-based communications have not kept pace with the march of progress, and population density is not sufficient to justify the large, expensive ground complex needed to tie into the commercial communications satellite network. The utility of the direct broadcast satellite in such remote areas was explored in a program called the Health/Education Telecommunications (HET) Experiment, jointly sponsored by NASA and the Department of Health, Education & Welfare. In HET, ATS-6 was used in an extensive study which checked out such potential applications as improving remote area health care and conducting educational seminars by means of satellite communications.

In a follow-on to that effort, NASA and the Canadian Department of Communications are working jointly on a project called Communications Technology Satellite. Launched last year, CTS has transmitting power levels 10 to 20 times higher than current commercial communications satellites. Like ATS-6, the new satellite provides reception by low-cost antennas affordable by most communities. The program contemplates a number of public service experiments, such as satellite-supported medical treatment, classroom educational programs, and high-speed data transfer for businesses.

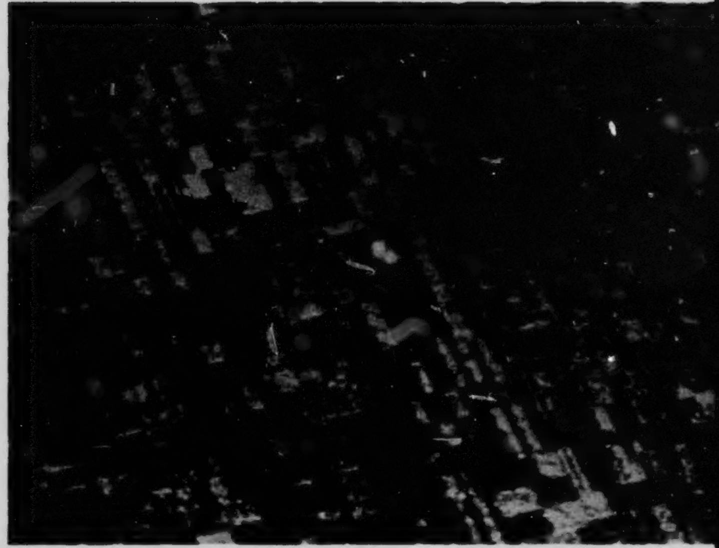
ATS-6 and the Communications Technology Satellite are examples of NASA's direct applications programs, wherein aerospace technology is being developed for public benefit. Another example is the meteorological satellite.

Weather by Satellite

Now familiar to everyone is the National Operational Meteorological Satellite System, in which NASA-developed satellites operated by the National Oceanic & Atmospheric Administration provide cloud-cover photographs and other information for interpretation by weather forecasters. The NOAA network has considerably enhanced routine weather prediction, but perhaps the most striking benefit is in the detection and monitoring of severe storms—hurricanes and large frontal systems of potentially destructive nature. The beneficial impact of meteorological satellites is underlined by this fact: since the inauguration of the operational satellite system in 1966, no major storm system has gone undetected at any point on the globe.

Not as familiar are some of the other uses of meteorological satellites. For example, the Geostationary Operational Environmental Satellites (GOES) are equipped with data collection systems for the acquisition and relay of environmental information from widely dispersed surface platforms, such as river and rain gages, seismometers, tide gages, buoys, ships, and automatic weather stations.

Weather satellite information is being used routinely to track the motions of the Gulf Stream for fishing interests and for the routing of coastal shipping. The U.S. Coast Guard uses cloud imagery to determine low cloud and fog conditions over the route of the International Ice Patrol, allowing cancellation or redirection of reconnaissance flights. Satellite infrared imagery provides the basis for drawing composite ice charts of Great Lakes and Alaskan coastal waters. Quantitative estimates of snow cover and rainfall over both the United States and Canada are made possible by satellite data.



This image, taken by a Landsat earth resources satellite, displays the satellite's utility as an agricultural assessment tool. Landsat's imaging equipment can be programmed so that different crops appear in different colors. In the photo, which covers a 14 nautical mile span of Montana, winter wheat is dark tan, spring wheat dark blue and barley red. Areas in light tan are those already harvested and light blue represents unplanted land.

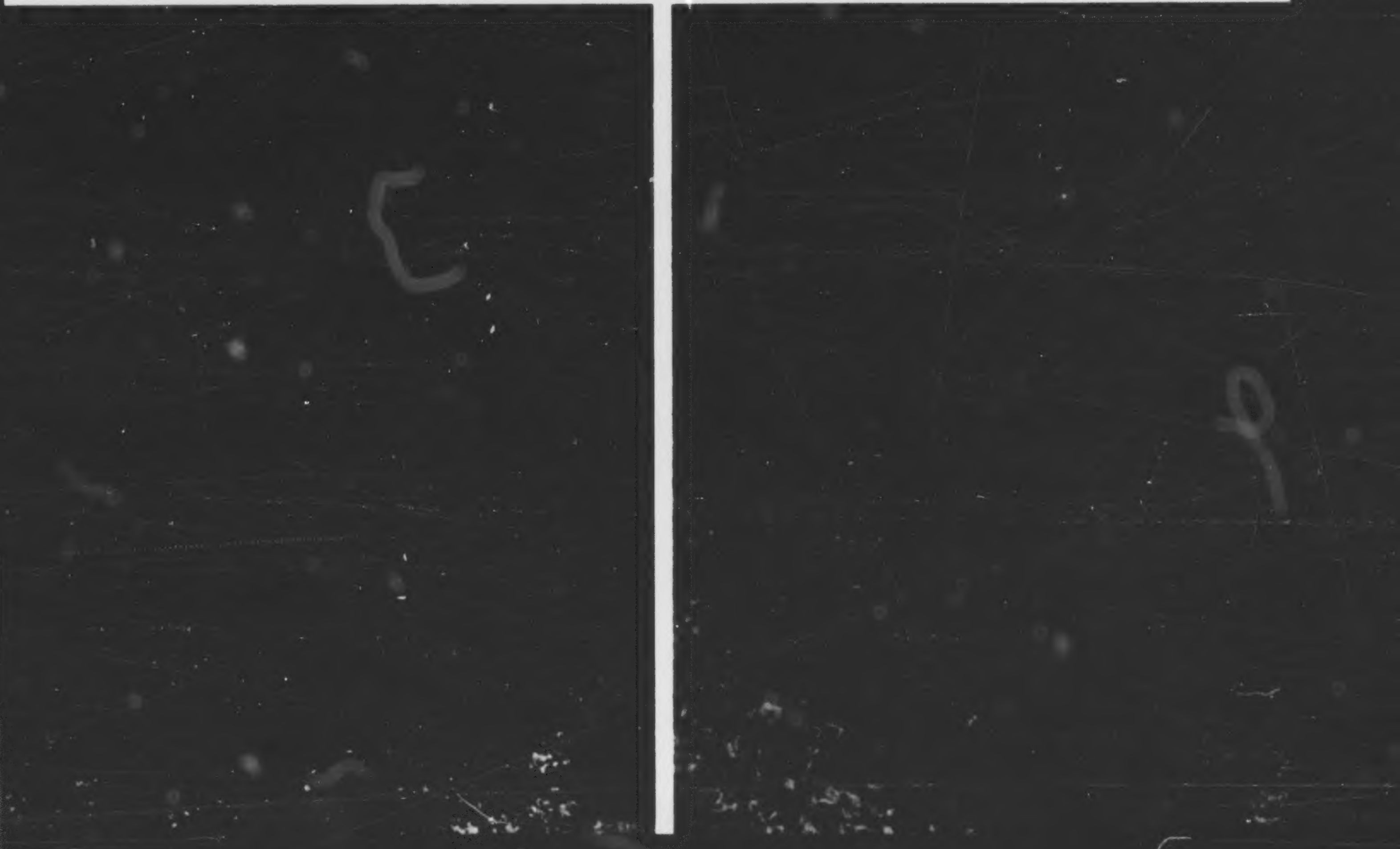
The Nimbus research satellite program focuses on demonstrating advanced technology for detecting and monitoring air and water pollution from space. An important future project is Nimbus G, scheduled for launch next year. For the first time, this satellite will provide global data on concentrations and distributions of many stratospheric gases and aerosols. This information may shed important light on a topic that has received wide public attention in recent years—the atmospheric chemistry affecting the stability of Earth's protective ozone shield. A companion satellite, planned for launch at about the same time, is the Stratospheric Aerosol and Gas Experiment (SAGE), which will develop data for near-global maps of the stratospheric aerosols so important to Earth's climate.

Monitoring Land Use and Resources

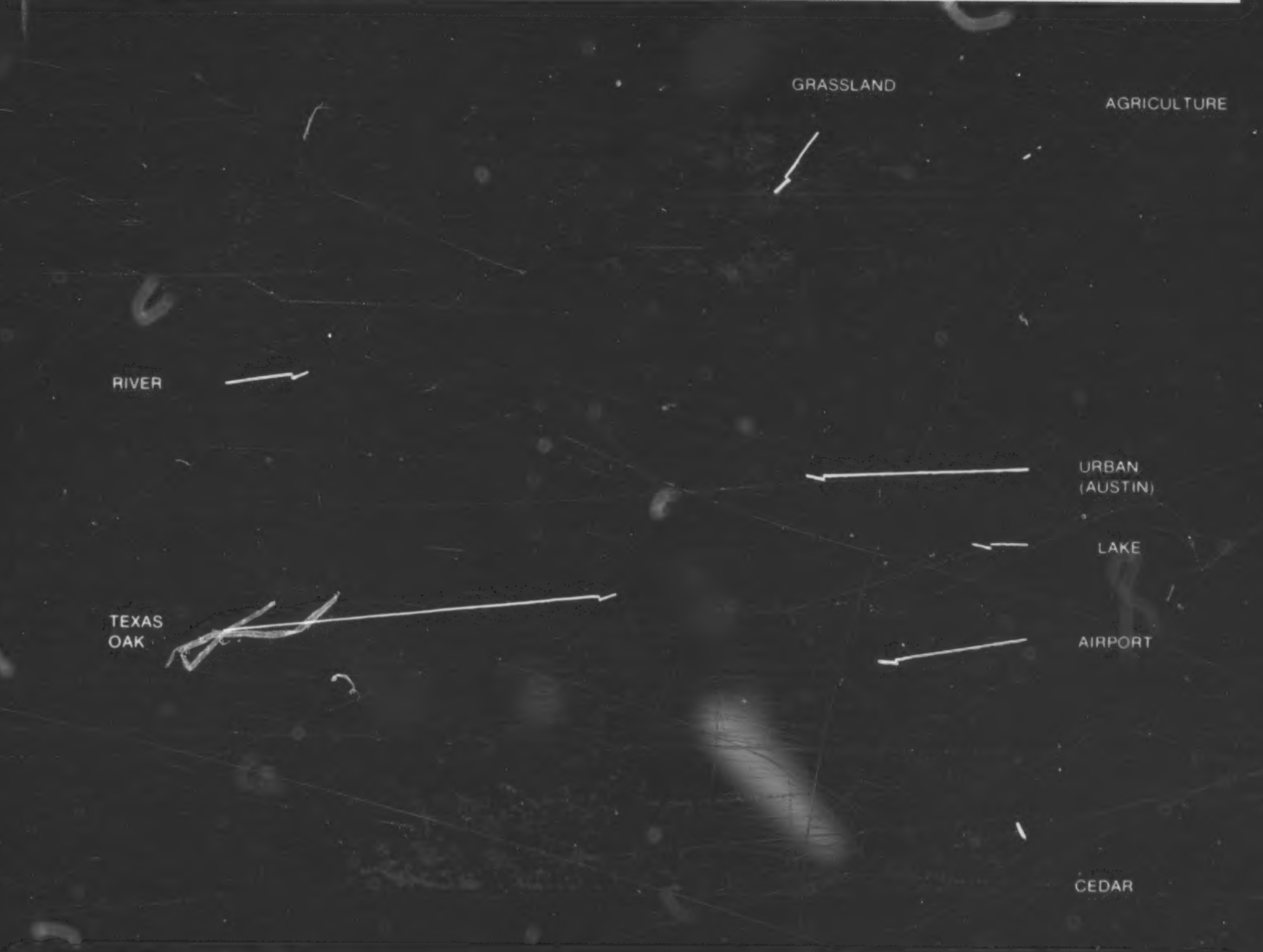
An applications program with sweeping possibilities for benefit here on Earth is Landsat, the Earth-surveying satellite. Two Landsats now circle the globe and between them they have the potential to scan the Earth, except for polar and cloud-obscured regions, every nine days. They provide information of Earth conditions in digital form and in pictures that offer enormous practical benefit in managing the planet's resources.

The Landsat view from space offers several advantages to scientists, engineers, planners and others. Landsat makes it possible to look at large portions of the Earth at one time—over 13,000 square miles (larger than the state of Maryland) in a single picture —thereby revealing great features, such as geologic faults, that are impossible to see from near-Earth. The repetitive coverage provided by the continuously orbiting satellites allows monitoring of dynamic Earth processes, such as crop growing conditions and changing land use over time. Landsat's ability to view the entire planet within a short period of time enables a whole new dimension of interregional comparisons of such activities as urban growth and land use patterns.

Although Landsat provides pictures of Earth it is not, strictly speaking, a photographic satellite. Its principal Earth-viewing instrument is a multispectral scanner, which has several important capabilities. The scanner is able to acquire valuable resources and environmental information not only in the visible wavelengths but in parts of the spectrum that are invisible to the human eye and to cameras. The scanner can acquire data in a number of wavelengths at once, allowing analysts to view Earth in



These Landsat images of the Mississippi River show the value of imaging satellites in flood assessment. At left, the river is at normal level, at right it is in flood. Comparison reveals the extent of flooding and identifies flood-prone areas for planning purposes.



This Landsat image of Travis County, Texas, illustrates the satellite's application as a land management tool. Each shade of color represents a particular land use category, such as urban, forest, and farm land. Landsat images have also been used by Texas state agencies for statewide water surveys, coastal zone management, and identification of wild life areas.

different perspectives and "add up" the information obtained. The digital data produced can be processed by computer, a tremendous aid to the human interpreter. The numerical data is quantitative (like saying a child has a temperature of 102.5 degrees F.) rather than a qualitative (like saying the child feels hot); in science, quantitative measurements are far more desirable than qualitative measurements. Finally, Landsat imagery has less distortion than is found in aerial photographs taken at lower altitudes.

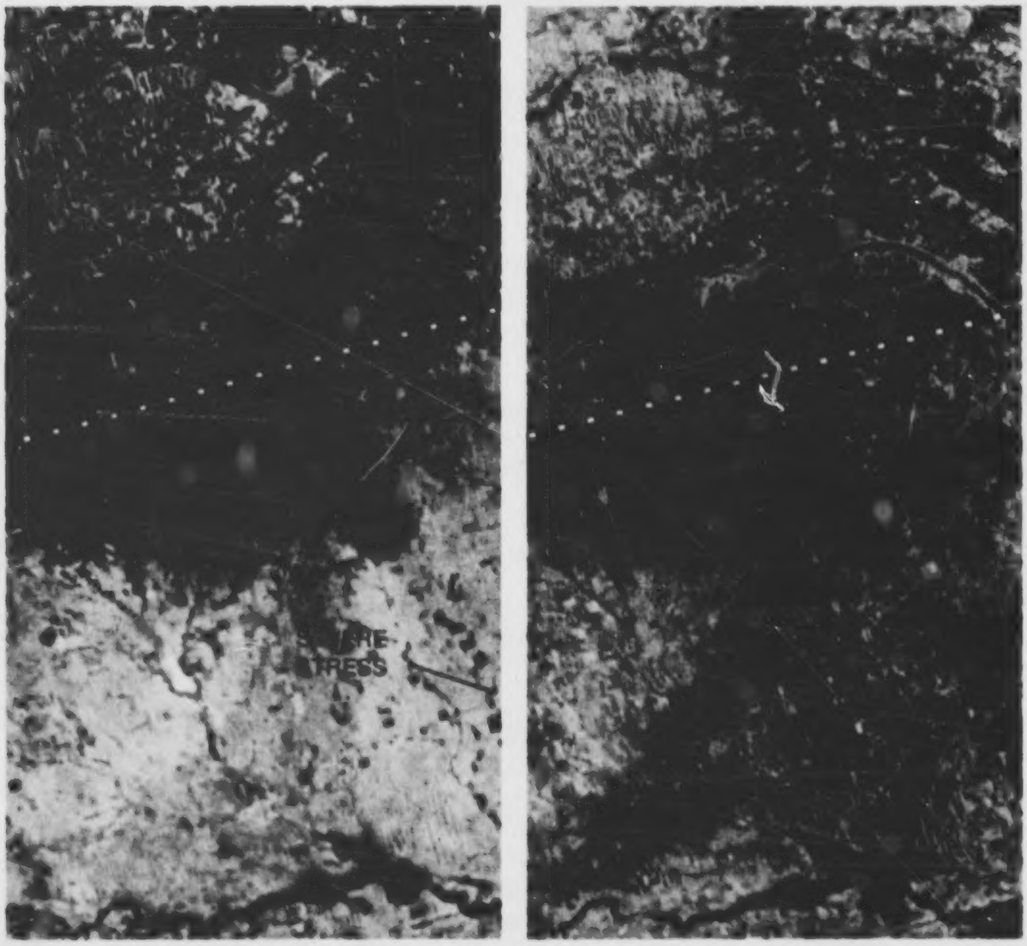
Landsat images are created on Earth from digital data obtained by the multispectral scanner, which employs a combination of radiation detectors, a mirror, and an Earth-viewing telescope. As the telescope scans the Earth, visible and near-infrared light waves reflected from Earth strike the mirror. The mirror bounces the lightwaves into banks of detectors that separate the light into four spectral bands—red, green, and two near-infrared bands (infrared is not visible to the human eye). The light in each band is further separated into 64 levels of brightness and this information is converted into electronic signals. Landsat's transmitter sends the signals to Earth receivers at 15 million "bits" per second, and a computerized signal-deciphering system at NASA's Goddard Space Flight Center in Maryland translates the flow of data into imagery on photographic film. Although you can buy a Landsat photo for as little as ten dollars, the satellite's pictures are extremely valuable in terms of their potential for making our planet more habitable.

One example of the exceptional utility Landsat offers is the project known as LACIE, or Large Area Crop Inventory Experiment. An inventory of crops is important because it provides the basis for predicting yield and planning distribution. The U.S. has a highly accurate ground-inventory system but most other countries, whose crop-yield information is important to us, lack such data.

Various types of vegetation reflect light or emit radiation (like heat waves) in different bands of the spectrum and in different intensities. Landsat's sensitive detectors can often tell the difference, and can be programmed to "see"one particular kind of vegetation. In the initial test, LACIE inventoried wheat in the Great Plains of the U.S. The experiment then was extended to embrace agricultural regions of other areas of the world. Landsat later will be expanded to develop a capability to inventory different crops.

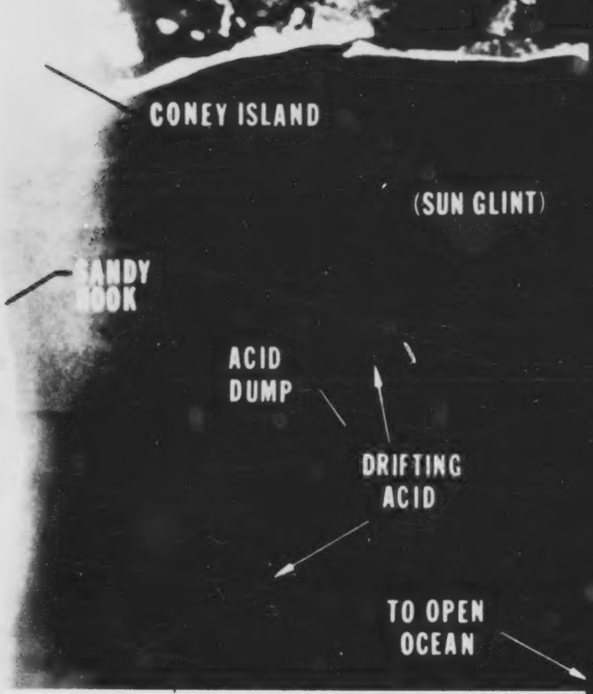
Landsat offers other agricultural benefits. For example, diseased crops can be made to show up in colors different from healthy crops. Since early detection of blight allows prompt corrective measures to prevent the spread of disease, this Landsat capability presents a tremendous prospect for more effective management of global food resources.

Agricultural use is just the beginning of Landsat's exceptional utility. The satellite has demonstrated potential for detecting water pollution, monitoring floods so their devastation can be lessened, assisting in exploration for new oil and mineral resources, recording surface-mined land, inventorying sources of fresh water over very large areas, providing maps

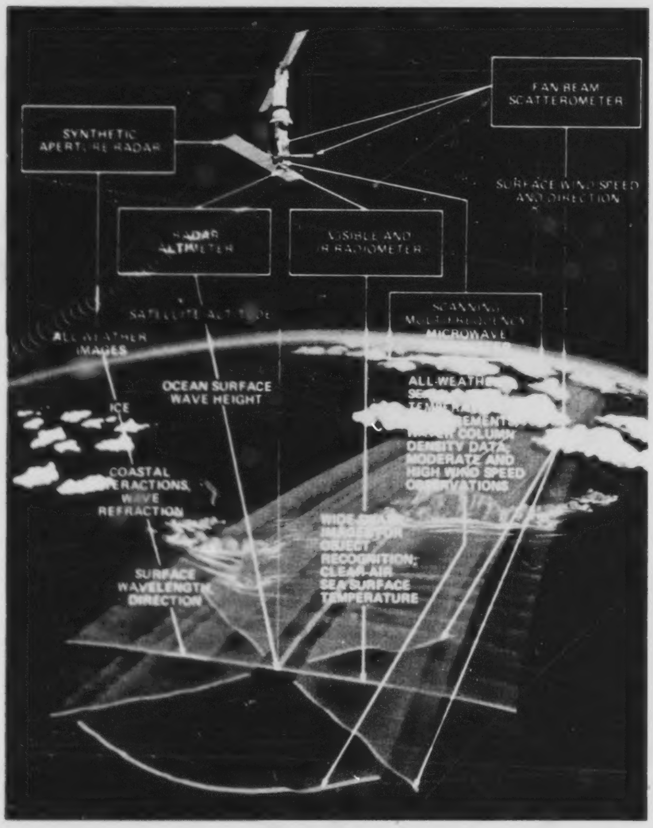


Another important Landsat capability is detection of crop disease. These comparison pictures show the different images produced by Landsat's scanner of healthy crops (right) and "stressed" crops. Early detection of blight allows prompt corrective action to prevent the spread of disease.

NASA and the National Oceanic & Atmospheric Administration are using remote sensing techniques to monitor the effects of dumping sewage and industrial wastes in oceans. Remote sensing imagery has demonstrated potential for detecting locales and amounts of pollutants and how they spread after dumping. This image, part of an investigation of dumping in the New York Bight, was taken by a multispectral scanner aboard a NASA high altitude aircraft.


CONEY ISLAND
(SUN GLINT)
SANDY HOOK
ACID DUMP
DRIFTING ACID
TO OPEN OCEAN

Seasat-A, scheduled for launch next year, will report continuously on changing ocean conditions such as wave height and direction, surface winds, water temperatures, current and tide patterns, and ice field locations. Ocean monitoring on a global scale can assist in ship design, ship routing, storm and iceberg avoidance, coastal disaster warning, and guidance of fishing fleets to most productive waters.


SYNTHETIC APERTURE RADAR
FAN BEAM SCATTEROMETER
SURFACE WIND SPEED AND DIRECTION
RADAR ALTIMETER
VISIBLE AND IR RADIOMETER
SCANNING MULTIFREQUENCY MICROWAVE
SATELLITE ALTITUDE
ALL-WEATHER IMAGES
OCEAN SURFACE WAVE HEIGHT
ICE
COASTAL INTERACTIONS, WAVE REFRACTION
SURFACE WAVELENGTH, DIRECTION
ALL-WEATHER
WATER COLUMN DENSITY DATA, MODERATE AND HIGH WIND SPEED OBSERVATIONS
WIDE-SWATH IMAGERY FOR OBJECT RECOGNITION; CLEAR-AIR SEA SURFACE TEMPERATURE

of uncharted regions, monitoring sea ice, surveying forests and assessing fire damage--the list goes on and on. The two Landsats, a third about to join them, and their even more advanced generations of the future will provide a means for studying the constantly changing conditions of Earth for the benefit of people everywhere.

To complement Landsat, NASA is developing an oceanographic satellite called Seasat-A for launch in 1978. Seasat's assignment will be continuous reporting of ocean dynamics—such things as wave height and direction, surface winds, ocean temperatures, current and tide patterns, and ice field locations. Monitoring of these conditions on a global scale offers important benefits in a number of ways—for instance, ship routing, ship design, storm and iceberg avoidance, coastal disaster warning, and directing fishing fleets to most productive waters.

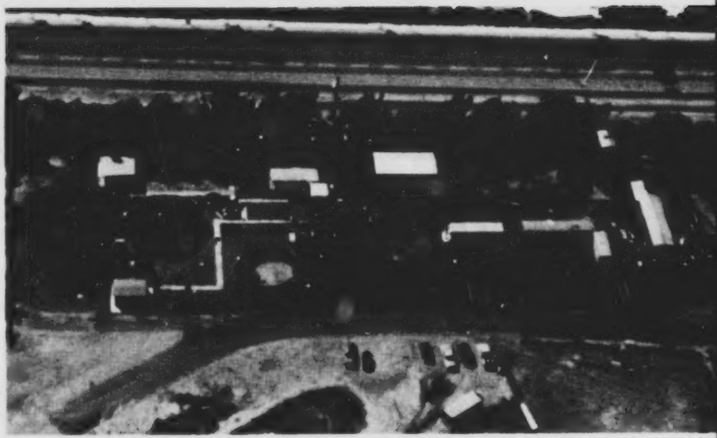
This picture of buildings at NASA's National Space Technology Laboratories shows how infrared technology can enhance energy conservation by pinpointing location of areas in industrial facilities which are experiencing heat losses. Taken by an airplane with an infrared scanner, the picture is a computer-developed representation rather than a photograph. In the infrared view of NSTL's hot water producing facility, bright yellow and white areas indicate high levels of heat loss due to leaks or deterioration of insulation. The picture gives maintenance personnel a trouble map for corrective action.

Non-Space Applications

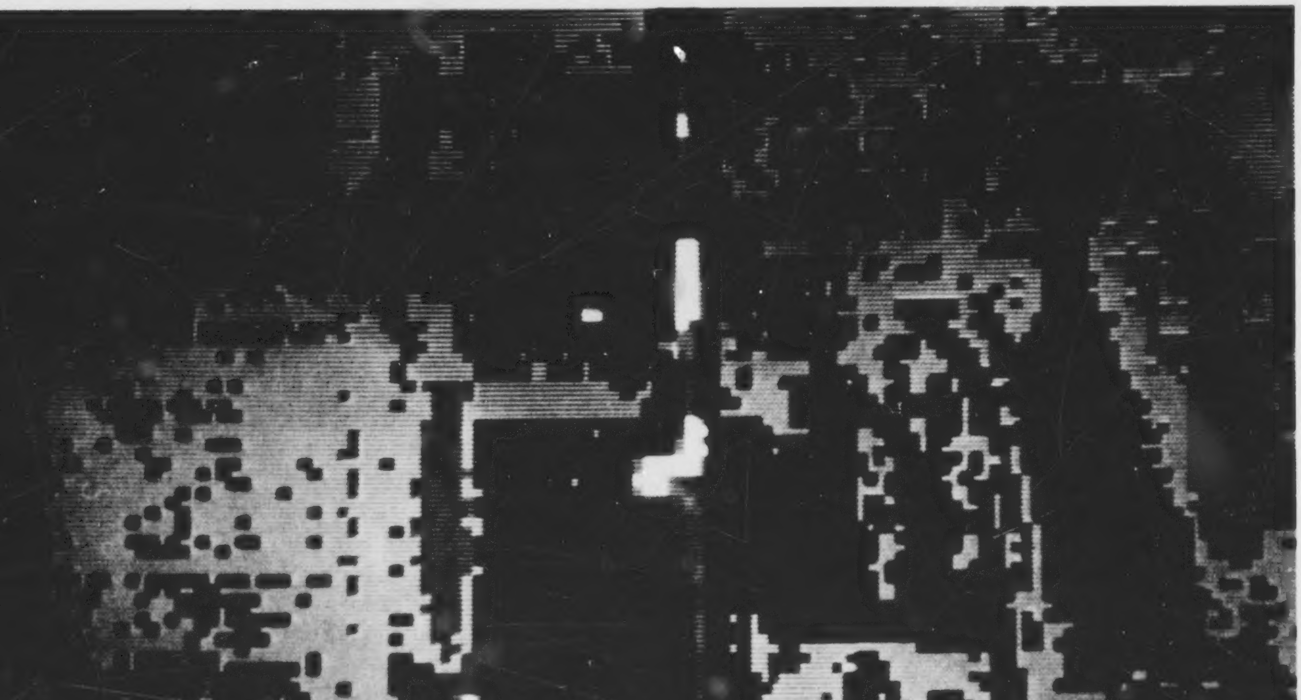
Aside from the satellites, NASA's Office of Applications conducts technology applications programs, originated by NASA personnel who conceive of innovative civil systems while engaged in their normal aerospace activities. Programs of this type are designed to meet specific, identifiable civilian needs by providing solutions that are operable on the ground or within the atmosphere. They are derived from the technological and management capability that NASA acquires in its primary activities. An example of a major innovation is ACTS (Activated Carbon Wastewater Treatment System).

ACTS originated in space research at the Jet Propulsion Laboratory. An engineer, testing various materials in search of a lightweight rocket motor insulator, built a device for manufacturing carbon by "pyrolysis," or high-temperature heating without oxygen. Looking for a substance from which to make carbon, he discovered that sewage solids offered an excellent raw material. He also found that the resulting activated carbon was a fine agent for treating sewage.

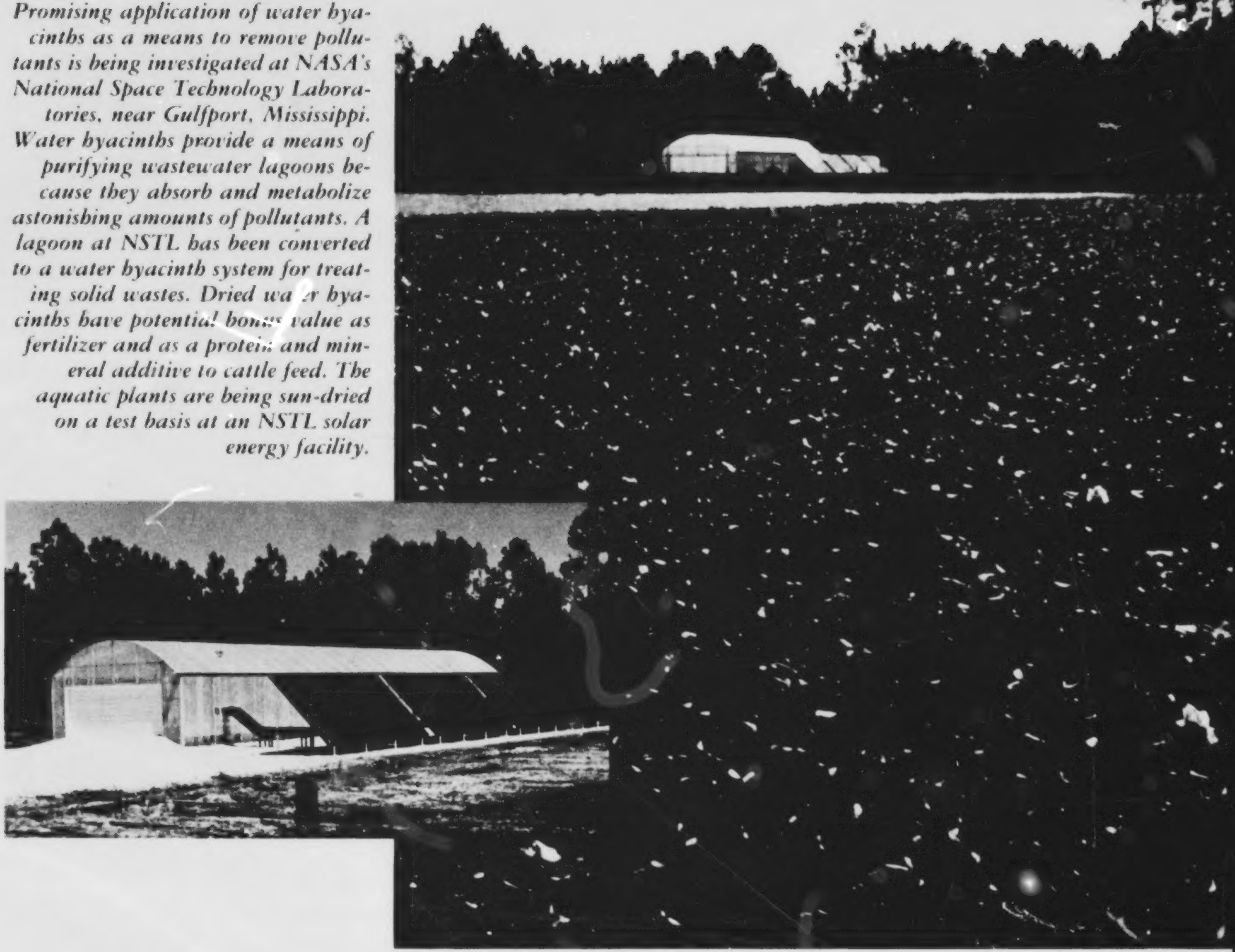
From these discoveries evolved the ACTS development, in which filtered solid sewage is burned to make activated carbon and the carbon in turn is used to filter sewage. The filtering process produces water as clean as that resulting from conventional methods, but offers a number of advantages in reduced costs.



This 1,000,000 gallon per day pilot plant in Orange County, California is evaluating a NASA-developed pollution control technique known as ACTS (Activated Carbon Wastewater Treatment System). ACTS is based on the knowledge that activated carbon is an effective agent for treating sewage, and solid sewage, in turn is an excellent material from which to make carbon. In the plant, filtered solid sewage is burned (without oxygen) to produce activated carbon and the carbon is used to treat the wastewater. The process yields water as clean as that resulting from conventional methods, but at significantly reduced cost.



Promising application of water hyacinths as a means to remove pollutants is being investigated at NASA's National Space Technology Laboratories, near Gulfport, Mississippi. Water hyacinths provide a means of purifying wastewater lagoons because they absorb and metabolize astonishing amounts of pollutants. A lagoon at NSTL has been converted to a water hyacinth system for treating solid wastes. Dried water hyacinths have potential bonus value as fertilizer and as a protein and mineral additive to cattle feed. The aquatic plants are being sun-dried on a test basis at an NSTL solar energy facility.



To prove the concept, NASA built a 10,000-gallon-a-day pilot plant, placed in operation at an Orange County (California) sanitation district facility. Encouraged by the results of several months of test operation, the sanitation district constructed a million-gallon-a-day plant under an Environmental Protection Agency grant. After several months of operation, the plant is living up to expectations. The system affords savings of more than 25 percent in construction costs, 10 to 20 percent in operating costs, and a major reduction of sewage disposal costs since the resulting waste product is only a small amount of ash. ash.

Another applications project promising future benefit involves the use of water hyacinths to remove pollutants. Long regarded as colossal nuisance because their rapid growth clogs rivers and streams, water hyacinths are getting a new image as useful and beneficial plants because of the discovery that they thrive on sewage. The plants absorb and metabolize astonishing amounts of nutrients and pollutants and therefore offer a means of cleaning wastewater lagoons.

The initial experiment in employing water hyacinths as a natural filtration and purification system was conducted in Bay St. Louis, Miss., which has a 40-acre watewater lagoon that receives raw sewage from 6,000 households. At the request of city officials, NASA researchers fenced off seven acres of the lagoon and planted water hyacinths. The plants flourished on a feast of sewage and soon produced dramatic results—a large part of the noxious lagoon became a clean, beautiful flower garden. As a result of this and other experiments, NASA scientists feel that water hyacinths show real promise for purifying polluted waters. They also have bonus potential as a source of fuel and fertilizer, and as a protein and mineral additive to cattle feed.

These few examples of satellite and ground system innovations are representative of a much broader NASA applications program which is producing significant direct benefits.

Spinoff from NASA's mainline programs is providing bonus value in derivative benefits ranging from simple conveniences to major problem solutions.

technology's second time around

Among the many fascinating experiments performed by the Viking Landers on the surface of Mars was one in which the robot spacecraft scooped up soil samples, analyzed them automatically and reported the findings to Earth.

That soil analysis system can be converted to a practical instrument for use on Earth. It has applicability in a portable unit for measuring soil moisture prior to road construction to assure proper compaction of the road bed. This technique is more rapid and less expensive than existing methods for testing surfaces because the analysis can be performed on-site.

Spinoff pervades almost every facet of our lives. The steady stream of technology transfer has found its way into brain surgery and cancer treatment, home design and kitchen appliances, pollution control and waste disposal, fire prevention and protection for firefighters, law enforcement and airline safety, transportation, energy systems, industrial processes, food products, bridge construction, farm machinery—the list can be extended to catalog length.

This child is wearing a "Pacer," a cardiac pacemaker whose battery can be recharged through the skin without pain or inconvenience to the wearer. Developed by the Applied Physics Laboratory of Johns Hopkins University, the Pacer represents a major advance in heart-assist devices in that its recharging capability eliminates the recurring need for surgery to implant a new battery. The Pacer's nickel-cadmium battery, rechargeable in 90 minutes, has a lifetime of 10 to 20 years. It stores enough energy for eight weeks operation, but in normal use it is recharged weekly. The basic pacemaker is a spinoff from miniaturized solid-state circuitry for spacecraft. The improved rechargeable device was based on NASA technology developed for satellite power systems.

Spinoff is not often recognized as such, perhaps because we accept technological advance as a natural heritage of 20th Century life. You rarely question the origin of a useful innovation. You might wear a rechargeable pacemaker, or admire the lines of a new auto, or use a mini-calculator, or buy a hunting jacket, or install a homeguarding device—unaware that aerospace technology contributed in part or *in toto* to the existence of all these products.

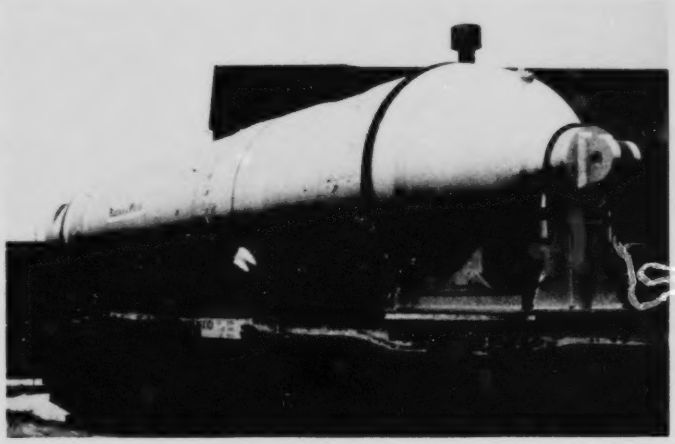
Spinoff does not "just happen;" it results from a carefully planned, well-organized effort. To assure American taxpayers maximum return on their aerospace investment, NASA's Congressional charter directed the agency to spread as widely as possible the knowledge acquired in its mainline programs and to promote actively the secondary use of this wealth of technology. This Congressional mandate led to the establishment, in 1962, of NASA's Technology Uilization program, which seeks to promote technology transfer by stimulating industrial interest and by providing assistance to potential users.

Over the past 15 years, thousands of aerospace-derived innovations have been transferred to the private and public sectors. Many represent only moderate increments of economic gain or lifestyle improvement; some are substantial advances with values running into the millions of dollars. Some are almost directly transferable; most have to be adapted for secondary use. In the aggregate, they amount to significant benefits to our mode of living and to the national economy.

Spinoffs are brought to the marketplace in a variety of ways and through the interaction of several mechanisms.

NASA maintains one of the world's largest libraries of computer programs called COSMIC (for Computer Software Management & Information Center). About 1,600 programs—or "software packages"—are available. They embrace virtually every field of computer application. COSMIC programs can perform tasks as diverse as determining a building's energy requirements, designing electronic circuits, optimizing mineral exploration, and drawing maps of water-covered areas using NASA satellite data. A customer can get a software package for a fraction of what it would cost to start from scratch. With an increasing number of business firms turning to automated operation for greater efficiency, this facet of the spinoff process is paying big dividends to users.

An example: Among the many software packages is a structural analysis program called FEDGE. The Babcock & Wilcox Company, Alliance, Ohio, used FEDGE in the design of a nuclear steam generator pressure vessel. FEDGE provided substantial savings by allowing computer-modeling of the structure, as opposed to manual generation of the mathematical data.



Design of this 750-ton nuclear steam generator pressure vessel was aided by a NASA computer program called FEDGE (Finite Element Data Generation). Substantial savings were realized by using FEDGE to computer-model the structure, as opposed to manual generation of the extensive mathematical data involved. Developed by Jet Propulsion Laboratory, FEDGE is one of many computer programs available to industrial firms through NASA's Computer Software Management and Information Center.

NASA further promotes technology transfer through its seven Industrial Applications Centers, which offer the world's largest bank of technical data—more than eight million documents. This vast storehouse of technical knowledge can be a bonanza for businessmen exploring new markets, looking for answers to problems, or simply trying to stay competitive by keeping their technical people abreast of the latest developments in their fields. For a nominal fee, a client can get a computer search of the literature available in his particular area of interest and the help of applications engineers in applying the results of the search.

Example: The Youngstown Sheet and Tube Company, a division of Lykes Corporation, specializes in the manufacture of flat rolled steel, tubular and bar products. Since 1974, the company has had a continuing participation agreement with the Knowledge Availability Systems Center, the NASA Industrial Applications Center at the University of Pittsburgh. The Center has carried out more than 30 different searches for Youngstown Sheet and Tube. One of the searches led to a company decision to change an industrial process; the change brought about savings of several hundred thousand dollars a year and a product yield improvement of over a million dollars a year. In another instance, when Youngstown was making a decision between two different types of production equipment, the Center

In photo, a part of the steel manufacturing facilities of the Youngstown Sheet and Tube Company. The company has a continuing participation agreement with the NASA Industrial Applications Center at the University of Pittsburgh, which conducts computer searches among some 8,000,000 documents as an aid to business firms. On two separate occasions, Youngstown Sheet and Tube realized savings of several hundred thousand dollars a year as a result of information produced from the world's largest bank of technical data.

uncovered detailed evaluations of the equipment, allowing increased certainty in the decision. Youngstown officials estimated the cost benefit of the decision at several hundred thousand dollars annually.

Also under the Technology Utilization program, NASA assists in the solution of public-sector problems in such areas as safety, health, transportation, and environmental protection. NASA's role in this regard is adapting aerospace know-how to civilian use through "applications engineering"—essentially modifying aerospace products or processes to meet civil needs and conducting field tests to prove the redeveloped hardware.

Example: Traditional firefighters' breathing apparatus is heavy and cumbersome, which induces a problem explained by a Boston deputy fire chief: "Many men prefer not to use the equipment. They risk being overcome by smoke, but if they use the old masks the weight can cause them to collapse from heat and exhaustion."

As a countermeasure, NASA's Johnson Space Center developed a lightweight air bottle patterned on technology originally developed for rocket motor casings. JSC also redesigned the breathing system's pack frame and harness. The resulting pack, produced by Scott Aviation, Division of A-T-O Inc., Lancaster, N.Y., weighs 40 percent less than existing equipment and seems even lighter because of better weight distribution. In 1976, Boston became the first municipality in the nation to introduce the NASA-developed breathing apparatus as regular equipment. Mine Safety Appliances Company, Pittsburgh, Pa., has also introduced the innovative NASA air bottle into their new lightweight firefighter's breathing apparatus.

In an associated effort, NASA is working with the Department of Commerce's National Fire Prevention & Control Administration in Project FIRES (Firefighters' Integrated Response and Equipment System). FIRES seeks to improve the firefighters' "envelope," the various elements of protective clothing and equipment used in action. Marshall Space Flight Center is handling laboratory investigation, developing new equipment and improving existing equipment, and conducting field-test engineering.

NASA sponsors application teams, composed of experts in several different technological disciplines, to work with public-sector groups. There are three biomedical and two technology application teams located at research institutes and universities. They attack specific problems on the premise that aerospace knowledge might offer lines of solution where none is otherwise apparent.

Example: The biomedical application team at the Research Triangle Institute, N.C., studied a problem sometimes experienced by those who suffer from arthritis or have suffered an injury, a stroke, or a bad burn: when a hand is immobilized for a long period of time it becomes progressively more rigid due to lack of exercise. Treatment requires a trained therapist to work the fingers for long periods daily, a painful process that is tedious to the patient.

The team came up with a simple but valuable spinoff from airflow control technology, a pneumatically-operated mitt which fits over the hand and automatically flexes the fingers. The patient thus can conduct his own therapy, able to cut off the machine whenever he wishes. The mitt frees the therapist for other duties, and there is a psychological bonus in the patient's knowledge that he can control the rate of finger movement and stop the pain whenever he wishes. Most patients will use the device for longer periods each day, and this factor—experience has shown—reduces overall therapy time by approximately half. The finger flexor is now in regular use at North Carolina Memorial Hospital and the device is being produced commercially by Bardon Enterprises Inc., Hampton, Va.

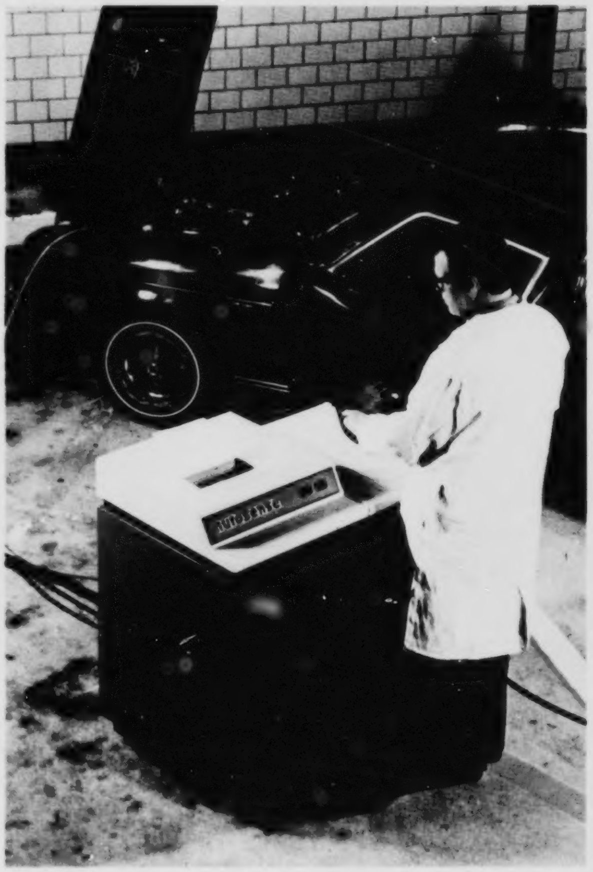
A NASA-developed firefighters' breathing system, consisting of a lightweight air bottle, redesigned pack frame and harness and other significant design improvements, is 40 percent lighter than earlier equipment. It offers improved safety for firefighters, who sometimes collapse from heat and exhaustion induced by heavy, cumbersome breathing apparatus. Photo shows breathing system being used by the Boston firefighter at the top of the ladder.

A spinoff from airflow control technology, the pneumatically operated mitt pictured is a therapeutic aid for rehabilitating the fingers of paralyzed or badly burned hands. Customary treatment requires a trained therapist to work the fingers for long periods daily, a process painful and tedious to the patient. Developed at NASA-Langley, the mitt flexes the fingers automatically, enabling the patient to conduct his own therapy and to stop the pain whenever he wishes by turning off the machine. The device frees therapists for other work and the psychological effect of the patient control is credited with halving overall therapy time.

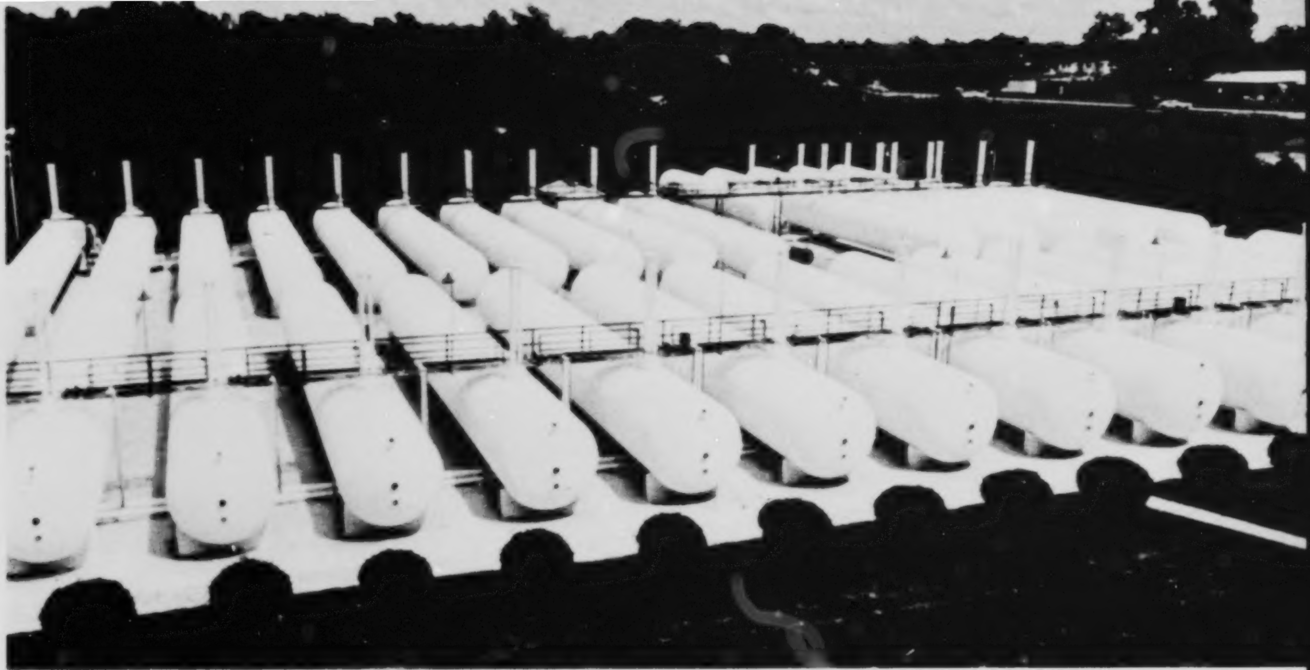
Product diversification by NASA contractors is another route by which aerospace technology is transferred to the non-aerospace sector.

Example: Under NASA contract, Hamilton Test Systems, Windsor Locks, Conn., developed an environmental control and life-support system for a prototype space station. Included in this development was a subsystem whose job it was to monitor the performance of various items of equipment, detect failures, and identify the specific malfunctioning unit. The technology thus acquired provided a springboard to a commercial product called "Autosense," a computer-operated diagnostic system for isolating malfunctions in autos and trucks. Autosense goes much further than some older diagnostic devices. In just 25 minutes, it can run through a "total auto health check," comparing operation of each part with factory specifications. The system is employed by used car, and even new car, dealers to satisfy customers that the vehicle they are buying is in tiptop shape. In use at repair stations, Autosense not only identifies trouble but also tells the mechanic—and the customer—why a faulty component is bad and how it may be fixed. After repairs have been made, a second health check printout shows the customer that the problem has been corrected.

Still another way in which technology transfer is effected is the movement to other industries of aerospace personnel, who take with them highly developed skills and know-how which have non-aerospace application. Sometimes they develop innovations stemming from their aerospace expertise and form new companies for commercial sale of these products.



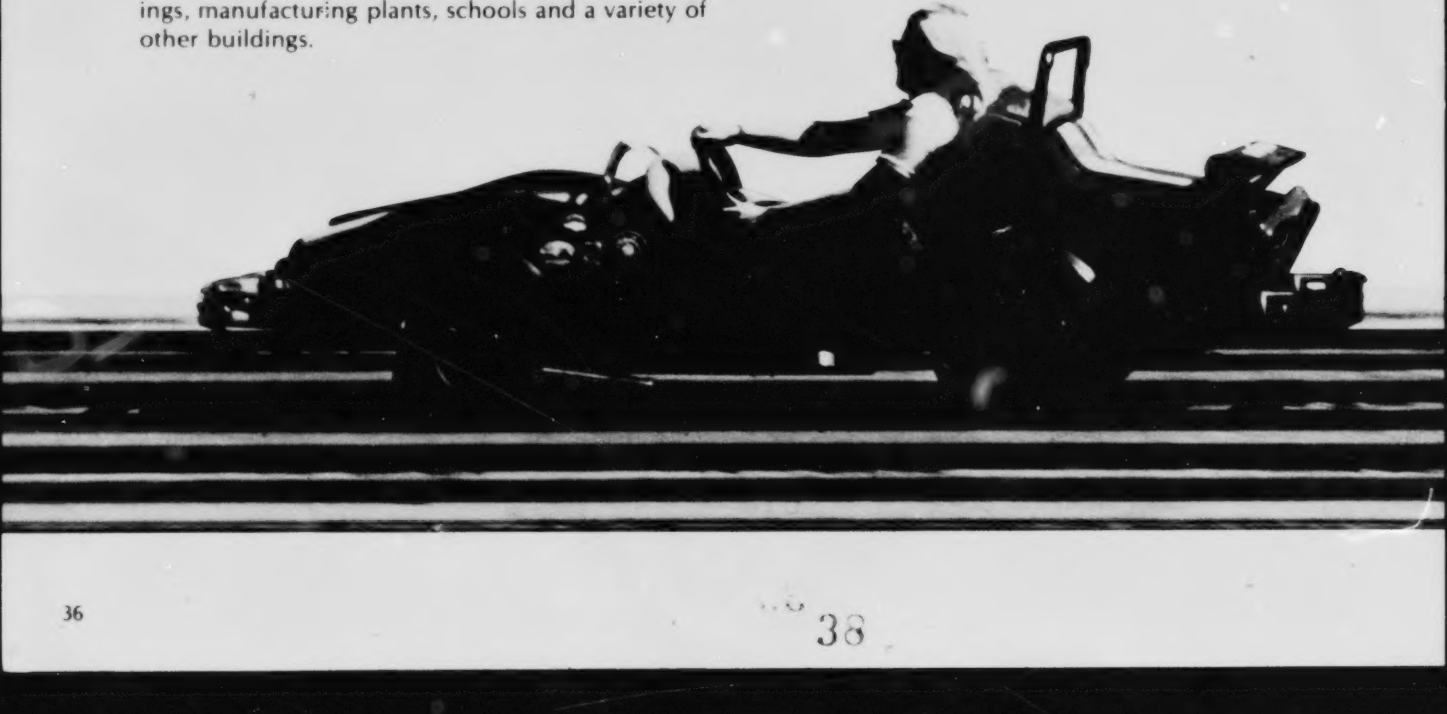
Technology from a spacecraft malfunction detection system provided the basis for a commercial product which diagnoses vehicle engine problems. Called "Autosense," it examines an auto or truck engine and provides a computer printout comparing each component with factory specifications. It tells both mechanic and customer why a particular part is malfunctioning and how to repair it. After repairs, Autosense verifies that the problems have been corrected.



This tank farm is protected against fire by a coating called Thermo-Lag, once used as part of the heat-shielding system for manned spacecraft. The coating contains chemical compounds which absorb heat from flame, retarding flame spread and delaying ignition of combustible materials.

Example: An inventor working for an aerospace contractor helped customize a previously-developed fire retardant coating for use as part of the heat shielding system for manned spacecraft. He acquired patent rights to the material and formed a new company called Thermo-Systems, Inc., now TSI Inc. of St. Louis, Mo. TSI is producing a commercial line of fire retardant coatings which are meeting widening acceptance in construction of office buildings, manufacturing plants, schools and a variety of other buildings.

Sold under the trade name Thermo-Lag, the coatings work on the principle of "sublimation." A subliming material—dry ice is the most familiar example—vaporizes, without melting, at a certain temperature, absorbing heat in the process. Thermo-Lag, which is sprayed or brushed onto building components like steel beams and electrical cables, contains compounds which sublime. When they sublime, they absorb heat from the flame as well as form a porous char layer which serves as highly efficient insulation. In this manner they retard flame spread and delay ignition of combustible materials. TSI offers a whole family of highly effective coatings for application to metal, wood and even paperboard.



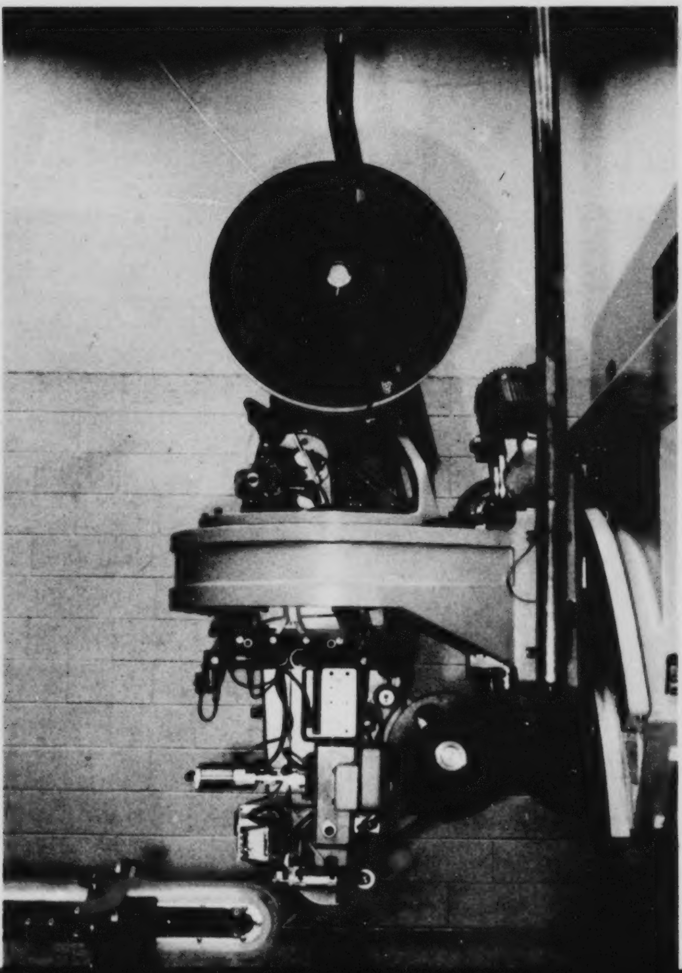
NASA also encourages non-aerospace businesses to take advantage of the technology wellspring. More than 10,000 distinct innovations judged to have commercial potential have been identified and are available to any company that wants to use them. To circulate the word, NASA publishes a quarterly book called **Tech Briefs,** which highlights the technical nature and significance of each innovation. Businessmen, scientists, and engineers can receive **Tech Briefs** simply by writing to NASA. Many companies and individuals have made profitable use of information contained in **Tech Briefs.**

Example: WED Enterprises is the division of Walt Disney Productions, Glendale, Cal. that conducts research and development for the entertainment operations of the company. A WED engineer read a Tech Brief that described a NASA report on fatigue life of roller bearings. Hoping to find an answer to a problem the company was experiencing with axle failures on the "Autopia" fun ride, he requested a technical support package from NASA's Lewis Research Center. Based on the information received from NASA, WED redesigned and replaced bearings of all 350 axles with a more durable bearing material.

The NASA patent waiver policy encourages NASA contractors to develop spinoff products.

Example: Winding fiber tape around a core is a method of producing components that are stronger yet lighter than conventional metal parts. Until recently, the technique was limited to parts of more or less uniform shape, because of the limitations of tape-winding machines. Under NASA contract, Goldsworthy Engineering Inc., Torrance, Cal., developed the prototype of a computer-controlled tape-placement head which can move simultaneously in six different axes to wind filament tape around parts with compound-curved shapes. NASA granted a waiver to Goldsworthy enabling the company to sell the machine commercially. It now is installed at The

In photo, a computer-controlled tape laying head is winding filament tape around a helicopter rotor blade to produce a blade that is lighter yet stronger than an all-metal blade. Winding tape around a core is a widely used method of fabricating lightweight components, but until recently the technique was limited to parts of more or less uniform shape. The tape laying head shown, which can move in six different directions, made possible tape winding of compound-curved shapes such as rotor blades. It was designed under NASA contract and further developed by the U.S. Army.



A NASA Tech Brief led to correction of an axle failure problem which caused breakdowns of the "Autopia" fun rides at Disneyland and Disney World. A Disney engineer read the Tech Brief and felt that the innovation it described might solve the axle bearing fatigue problem. He obtained the technical support package which suggested a different bearing material. Autopia axles were redesigned and replaced and since then have been operating trouble-free.

Boeing Co.'s Vertol Division in Philadelphia, where it is used to tape-wind advanced helicopter rotor blades that have many curves and varying thicknesses. The technique produces blades that are lighter but have greater stiffness than an all-metal blades. The economic advantage over manual methods is that automated tape winding reduces man hours from 4,000 to 350 per rotor blade.

Still another way industrial firms can profit from aerospace technology is through use of some 3,500 inventions patented by NASA. All of these inventions are announced, briefly described, and indexed in a semiannual **Patents Abstract Bibliography.** Interested firms can get non-exclusive, and sometimes exclusive, licenses for the commercial use of these inventions.

Example: A new type of solar energy concentrator was invented by an employee of Jet Propulsion Laboratory working under NASA contract. Many collectors used in solar heating or cooling systems employ mechanical tracking systems which turn the heat-collecting element to face the sun as it changes position in the sky. The invention eliminated the need for tracking. It is a simplified, economical arrangement of cylindrical lenses which focuses the moving sun on different collector elements and maintains continuous solar concentration. Recently, NASA granted an exclusive license to Owen Enterprises Inc., an American Indian-owned company in Wilmington, Cal., for production of the concentrator. The company fabricates the system at its Wilmington plant, transports parts to an Indian reservation in Arizona, and final assembly is completed by Indians living on the reservation.

Transfer innovations like the foregoing occur regularly, and the list of potentials continues to grow as new aerospace programs inject new know-how into the technology bank. Spinoff contributes to an improved way of life. More important, it can boost the economy. Technology transfer is a stimulus to greater productivity, hence to economic growth. It may not be panacea, but it represents a solid return on the national investment in aerospace research and development.

Most solar energy collectors used in solar heating and cooling systems employ mechanical tracking systems which turn the heat collecting element to face the sun as it changes position in the sky. A NASA-sponsored invention eliminated the need for tracking equipment by using lenses to focus the moving sun on different collector elements, thereby maintaining continuous solar concentration. NASA granted an exclusive license for production of the simplified, more economical solar concentrator to an American Indian-owned company.

Technology Twice Used

The following pages are devoted to benefits emerging from the secondary use of technology, in contrast to the direct benefits generated by NASA's mainline programs. Most of the spinoffs described are commercially available or in industrial use; others have not yet reached the market but have progressed beyond the conceptual stage to a point where their future availability seems likely. The breadth of the spinoff process is underlined by examples in categories of interest to many: homes, health, the environment, public safety, food, transportation, recreation, and industrial productivity.

A space-age house demonstrates how advanced technology can cut home fuel consumption by two-thirds and water usage by half, while providing bonuses in convenience and safety.

the house that NASA built

You are thinking of buying a home and, perhaps even more than the purchase price, you're concerned about the monthly outlay, the mortgage payment plus the utility bill. You know utility costs are climbing about 10 percent a year. Even water, once a small item in the homeowner's budget, is more expensive. In the not-too-distant future it's possible utility costs will exceed mortgage payments.

As a homeowner, how would you like to be relatively independent of rising utility costs, and draw instead on nature's bounty for a significant part of your energy needs? Or, to put it another way, how would you like a house whose special design and other features could save you over $20,000 in utility savings over a 20-year period and at the same time offer a variety of innovations that add up to greater comfort, convenience, security, and fire safety?

Such a house already exists. It's still in the demonstration stage, but all of its equipment and design features are now available to the public or will be within only a few years. Most of the systems evolved from some aspect of the space program. Each was selected to fit one of the guideline categories: money savings, safety, or comfort.

The home is called The Energy Conservation House (Tech) and it is located at NASA's Langley Research Center in Virginia. Tech House incorporates NASA technology, the latest commercial building techniques and other innovations, all integrated into a super-efficient home that offers exceptional savings to the individual family and potentially great national benefit in resource conservation.

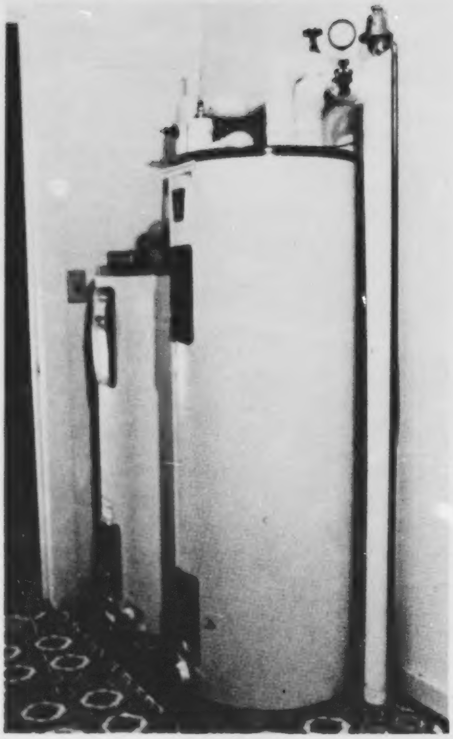
Starting this year it is planned that a family will live in the home for a year while NASA engineers monitor the new systems and put together a record of day-to-day performance. NASA officials believe the Tech House concept may influence near-term developments in home construction by pointing up the many benefits space-age technology offers.

Tech House is a contemporary, one-story, three-bedroom home which could be available commercially within five years for $45,000 to $50,000 (in today's dollars), a price range once in the luxury class but now close to the average. It has a large living room with a fireplace, dining area, kitchen, three bedrooms, two baths, laundry and garage. Because energy-conserving homes must be tailored to specific sites, Tech House is not a prototype of a mass producible design suitable for all locations. Rather it is a research and development laboratory for testing innovations that can be applied to some degree in all housing.

The principal energy-saving comes from using the sun's rays to heat the home and provide domestic hot water. Sunlight is captured by 19 solar collectors on the roof. These south-facing collectors are angled

Tech House, located at NASA's Langley Research Center, Hampton, Virginia, is a demonstration project in which aerospace and commercial building technology are combined to produce an energy-efficient home. Advanced technology offers savings to the family in utility costs and energy conservation.

Solar panels on the roof of Tech House provide the principal energy saving. They capture the sun's rays to heat water in pipes that run through the solar collectors. The heated water is then stored in a large, well insulated underground tank. A heat exchanger extracts heat from the water and blows it through ducts to warm the house.



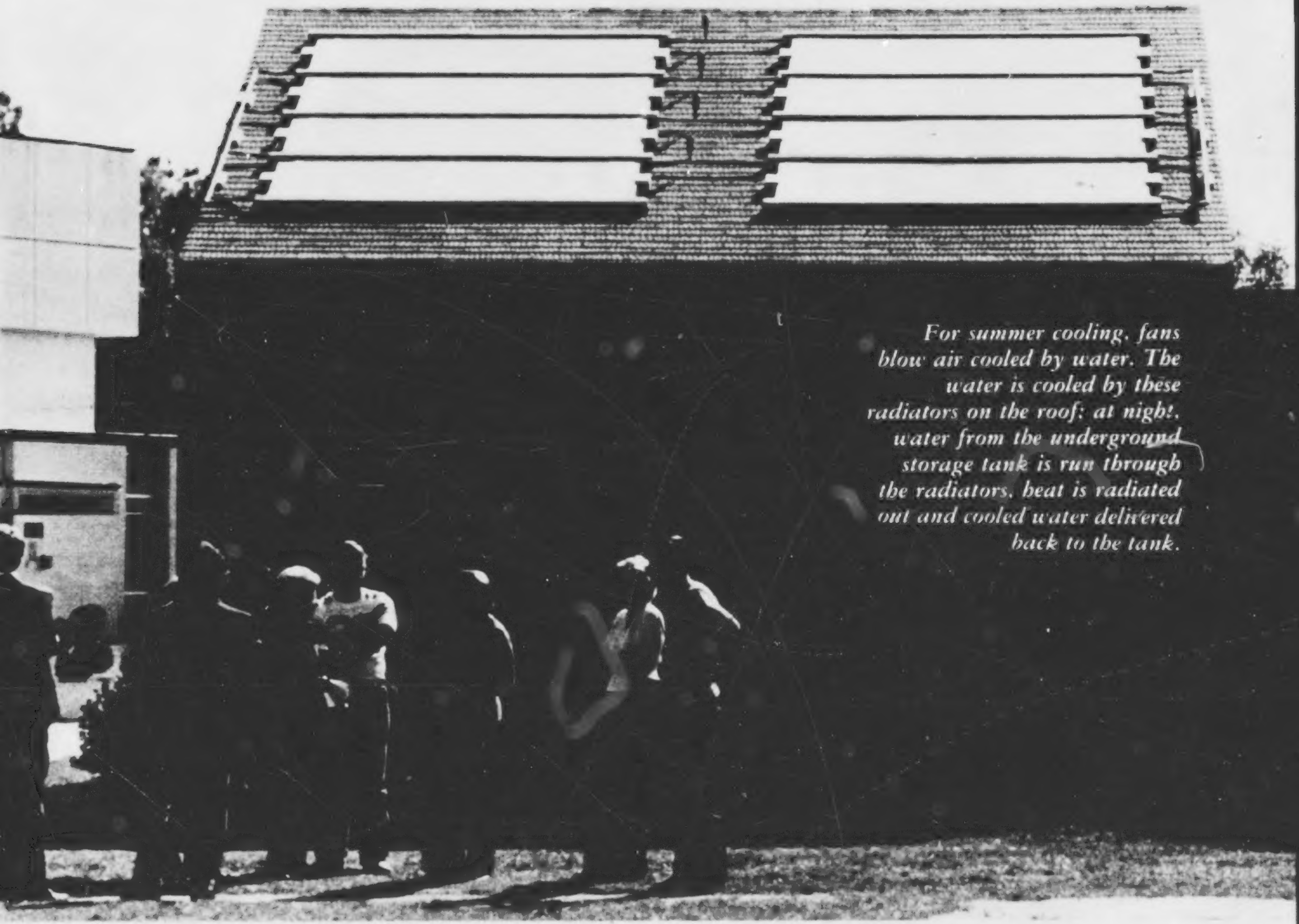
These two tanks make up a unique Tech House domestic hot water system. Water in one tank is "preheated" by solar energy, then fed into the other tank where a conventional electric heater further raises the temperature if necessary. Preheating takes care of 80 percent of the hot water energy requirement.

at 58 degrees for best exposure to the Virginia winter sun. (In other latitudes, they would be mounted at different angles; 21 degrees plus the latitude is optimum.) The individual solar collector has a glass outer plate and a metal inner plate, the latter coated with black chrome. The coating, developed in research on solar cells for spacecraft, prevents much of the heat from "reradiating," or escaping outward. Black chrome offers a 20 percent efficiency increase in the solar-collection process.

Running through the solar collectors are pipes through which water is circulated from a 2,000-gallon underground storage tank. The water is heated by the sun's rays to a temperature of 140 to 170 degrees. When the house needs heating, the hot water passes through a heat exchanger, which extracts the heat and blows it through ducts to warm the home. When heating is not required, the water bypasses the heat exchanger and goes directly to the tank for later use.

The system is largely independent of electrical energy, although an electric heat pump is also employed to transfer heat from the storage tank to the living space of the house.

Tech House is well insulated for energy savings. The principal insulation is fireproof Tripolymer foam which is sprayed onto walls and ceilings in thicknesses up to six inches.



For summer cooling, fans blow air cooled by water. The water is cooled by these radiators on the roof: at night, water from the underground storage tank is run through the radiators, heat is radiated out and cooled water delivered back to the tank.

The storage tank was designed to hold enough heat for five days of operation during overcast periods. After that, the temperature of the stored water will fall below 110 degrees. At that point the heat pump automatically goes into action, elevating the temperature to the requisite level, drawing the water from the tank and sending it through the heat exchanger for heat transfer to the living area. The water then is routed back to the tank.

For cooling the house, the heat pump system operates in similar fashion, except that it uses cool water; the cooler the water, the more efficient the pump. Water cooling is accomplished by radiators on the roof. At night, water from the storage tank is run through the radiators, heat is radiated out, and cooled water delivered back to the tank.

For domestic hot water, Tech House employs a two-stage "preheating" method. Water in one tank is heated by solar energy, then fed into another tank where an electrical system provides additional heating if required to reach a preset temperature level. Preheating by solar energy generally takes care of 80 percent of the hot-water energy requirement.

Much of the home's energy saving potential stems from the fact that it is well insulated. The floor is a two-inch cast of prefabricated concrete insulated with noncombustible gypsum foam. Tripolymer foam ranging from three and a half to six inches thick insulates the walls and ceiling. An excellent insulator, Tripolymer is nonflammable, nontoxic, odor free, and rodent-resistant.

The outer doors are built sandwich-fashion, with a core of polyurethane foam between the metal facings. The core has four times the density of wood and it completely blocks out cold because there is no

45

contact between the inside and outside metal surfaces. Magnetic weather stripping, such as used in refrigerators, seals the doors.

Windows not only are double-paned for insulation but also incorporate thermal shutters. Although not products of space technology, the Venetian blind type shutters are rolled down by motor or crank to form an exterior window seal.

The efficacy of all these insulating measures is evident in this fact: in conventional construction it would take a two-ton air-conditioning unit to cool the 1,500 square feet of living area, but Tech House can be kept comfortable by a one-ton system. And the superior insulation also sharply reduces noise transmission from the outside and from room to room.

More Energy Savers

In addition to insulation, Tech House boasts a variety of other novel design features and systems to reduce energy usage.

Exterior design includes a larger than normal roof overhang on the south wall. In winter months, when heat gain is desirable, sunlight can penetrate the south-facing windows. In the summer, when the shutters are rolled up to admit light, the overhang protects the home from direct sunlight because of the sun's higher angle.

A large skylight, centrally located above the foyer, admits radiant energy from the sun in the winter, helping to heat the house. The skylight can be opened to create a chimney effect for ventilation. In either winter or summer, the skylight admits daylight to the foyer and living area, reducing the need for artificial light during daytime hours.

Except for a glass screen in front of it, the fireplace appears to be entirely conventional, but it is not. An ordinary fireplace draws air from the comparatively warm room, wasting heat. The Tech House fireplace derives combustion air from outside through ducts. Heat from the fireplace radiates into the living room through the glass screen, but the screen keeps room air from escaping. Additional heat is gained from a conventional double walled metal firebox.

The grate on which the burning logs rest is composed of pipes through which water is circulated. The fire-heated water is passed on to the storage tank as part of the overall heat-capture system. Where the ordinary fireplace yields only

The large skylight over the foyer admits daylight to the living area, reducing the need for artificial light in daytime. It also admits radiant energy from the sun, assisting the solar collectors in heating the home, and serves as a ventilator.

The Tech House fireplace contains a number of innovations which make it considerably more energy efficient than conventional fireplaces. For instance, room heat is not wasted since air for combustion is drawn from outside. Also, the temperature of the water in the storage tank can be increased by circulating it through pipes in the fireplace grate. Bi-fold glass doors (not shown in photo) permanently attached to fireplace will radiate additional heat into the room. These reduce heat loss up the chimney. These special features increase the efficiency of the fireplace from the usual 10 percent to 50 percent.

10 percent of the heat produced, the Tech House system is 50 percent efficient.

The Tech House comfort control system also allows substantial energy savings over a period of time. The computer-directed system heats or cools only the rooms actually in use at any given time and maintains precise temperatures. To accomplish this feat of heating intelligence, a computer program is prepared based on the pattern of the occupying family's activities. If family habits change, the computer can be reprogrammed. A manual override can return control to the occupants when desired.

In case of a power failure, Tech House is lighted by an emergency electrical system developed by NASA for lighting the Skylab manned space laboratory. Individual "Satellight" modules use electronic fluorescent lamps that emit a great deal of area lighting with extremely low energy demand. Now widely used in industrial applications, Satellights feature exceptionally long life and are inexpensive to install. Three of them, strategically located, can light Tech House in an emergency.

Satellight modules are powered by a 12-volt battery, which can also be used to power the security and fire safety systems. The battery is charged by a single solar cell, mounted on the roof of the garage.

The standard power source for unmanned satellites, the solar cell is a silicon device which converts sunlight energy into electrical energy without any moving parts. Thus, the emergency lights and other Tech House equipment used infrequently, add nothing to utility costs.

Even light bulbs have been examined for cost savings. While not an energy-saver, a new device called the "Bulb Miser" saves bulbs. Known as a

Furniture coverings, curtains and carpets, and all other fabrics in Tech House, are made of fire retardant materials.

"temperature compensating thermistor", the Bulb Miser, which looks like a washer the size of a quarter, is inserted in the light socket. It is, in effect, an electrical shock absorber that prevents bulb burnout by surging current. It extends bulb life at least three times, often as much as 20 times.

The bulb saver is a minor item, perhaps. But all of the savings in Tech House are reckoned on a cumulative basis over a 20-year span—and how many light bulbs does a homeowner replace in the course of two decades?

Tech House Economics

How effective are all these design features and innovative systems with regard to energy consumption? That remains to be confirmed under actual living conditions by the year-long computer monitoring program soon to be under way. In the interim, however, a detailed study in which Tech House was compared with a contemporary home of equal size shows what can be expected.

Tech House enjoys its greatest energy savings in heating because it uses solar energy for a major part of the need. The supplemental heat pump does consume electricity when its use is required, but the electrical demand is reduced by the super-efficient insulation. The gains are impressive with regard to central heating; in terms of annual kilowatt hours of energy, Tech House uses only a fifth as much as a contemporary comparison home.

Solar pre-heating of domestic hot water affords a similar advantage; the energy requirement for Tech House is roughly a third that of the comparison house. In 11 other categories of measurement—air-conditioning, lights, refrigerator, oven, etc.—Tech House is designed to consume 12 to 60 percent less energy than a conventional house. A family of four in a typical house uses about 46,000 kilowatt hours of energy a year; in Tech House the same family would use only 15,000.

Energy usage is a big factor in economy and conservation, but water-use efficiency is also important to the homeowner. Water bills, like energy costs, are climbing and they can be expected to go higher, at about the 10 percent annual rate predicted for energy. Individual considerations aside, water conservation is essential to the national interest in view of growing concern about possibly severe water shortages in the future.

A potential solution to the water conservation problem is the total recycling system, in which waste water is recaptured, purified, and used over and over. However, such systems are not economically feasible and there is little chance that they will become cost-effective within five years, a basic guideline for selecting Tech House innovations. So designers compromised and built into the home a partial water reclamation system based on prior work at Langley Research Center on spacecraft systems for fluid recycling.

Most waste water in Tech House is reused for toilet flushing, which accounts for almost 40 percent of a typical American family's water consumption. Water from the kitchen sink, dishwasher and garbage disposal contains organic food particles which are difficult to treat and filter, so this water is not reclaimed. But waste water from the bathroom sinks, the bathtub, and laundry equipment is collected in a holding tank, chlorinated, filtered, and recycled as "gray water" for toilet flushing. Plumbing for the drinking water is entirely separate from the waste water recovery system. Toilet waste goes directly to the sewer.

Water savings are augmented by other means too. For instance, special nozzle inserts in shower heads and a smaller than customary commode tank have been installed. The combination of partial reclamation and usage-control devices makes for very impressive water savings. Tech House's family of four will use about 36,000 gallons annually, well under half the equivalent usage of conventional house occupants.

Langley Research Center conducted an economic study that compared Tech House with contemporary homes.

The study found that initially Tech House would have only minimal advantage, but with continually rising utility costs the difference becomes dramatic. After a little more than eight years, Tech House savings would pay back the investment in the innovative equipment that makes possible the savings. After that, net savings would accumulate. The average monthly gain would be $96.59 in today's dollars, which figures out to slightly more than $23,000 over a 20-year span.

Fire and Security Measures

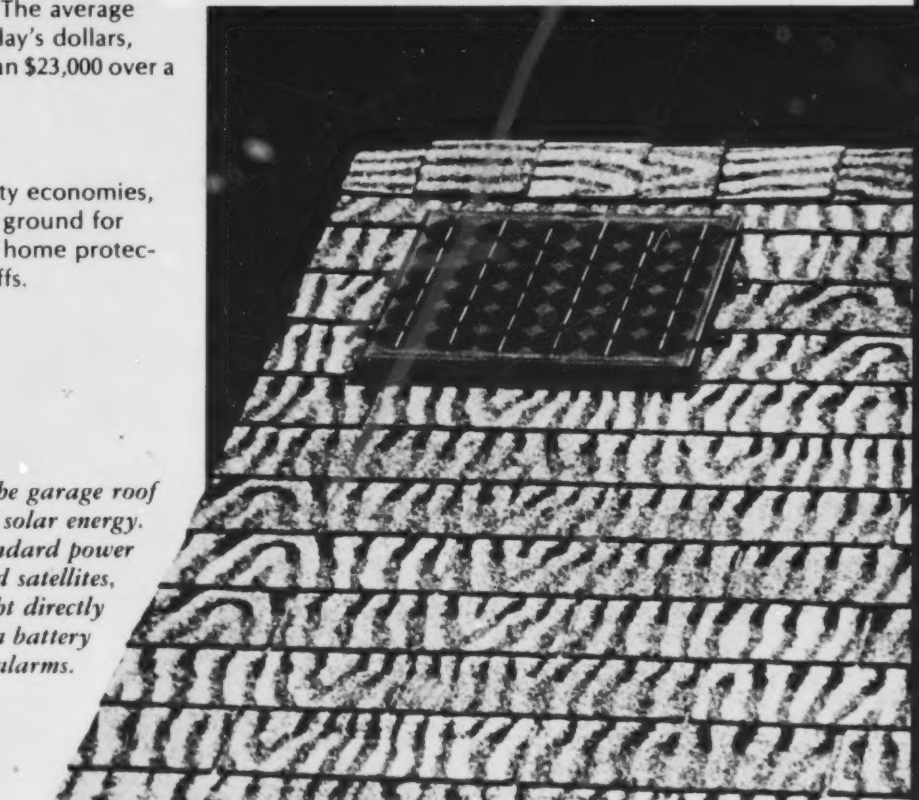
While the basic thrust is toward utility economies, Tech House also serves as a proving ground for devices designed to provide greater home protection, many of them aerospace spinoffs.

Fire safety begins with the home's insulation, all of it fireproof. Tripolymer, for instance, simply forms a charred crust when exposed to flame or intense heat and it immediately extinguishes the flame.

Most residential fires start in the contents of the home rather than the structure., For this reason, fire retardant materials are used throughout Tech House in curtains, furniture coverings, and carpets.

Although these materials will prevent the spread of fire and allow little property damage, there is the possibility of a retarded fire that would emit lethal fumes. The Tech House fire alarm system employs smoke detectors, sophisticated electronic devices that can sense combustion products before they are noticeable to home occupants. When smoke is detected, the system sounds a horn that will awaken the soundest sleeper, allowing time for escape. This equipment is highly important, in view of the fact that most fire-related deaths are caused by smoke inhalation rather than by burns. Such systems are available for your own home; there are about 20 different types on the market and they are relatively inexpensive.

Another safety device is the tornado detector, developed by a NASA engineer and available from Marketing Inputs, St. Louis, Mo. The unique detector is a light-sensitive device that attaches to the television set, which is tuned to any unused channel. Using the TV's electronics, the system detects a tornado within 18 miles of the home and sounds an alarm.



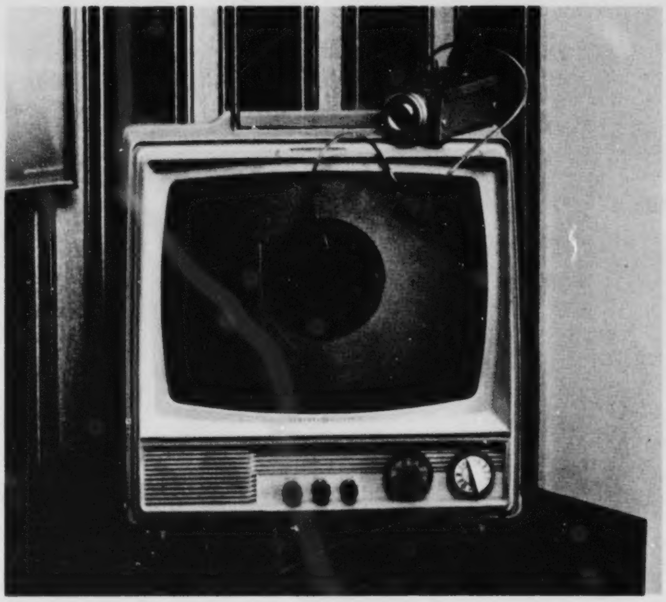
The small panel on the garage roof represents a different use of solar energy. It is a solar cell, the standard power source for unmanned satellites, which converts sunlight directly into electricity to charge a battery for powering security and fire alarms.

ENTRANCE LIGHT
SYSTEM Arming Control

The pushbutton panel at left in photo is the control box for the Tech House security system, which consists of wire intrusion detectors at the doors, windows and beneath the carpets. Occupants retiring for the night or leaving the house activate the system by punching a coded combination of numbers. After that, a step on the carpet or an attempt to force the doors or windows sets off a loud, siren-like alarm.

The alarm continues as long as the tornado is within that range, then cuts off automatically when the storm moves farther away. The home's thermal shutters, rolled down and securely locked, provide a degree of protection from flying debris during severe storms. The Tech House design takes due note that people are more security-conscious than ever these days. It offers an advanced security system that makes the home virtually intrusion-proof. The thermal shutters are part of it. When rolled down, they lock automatically and cannot be raised from the outside. Thus blocked, a determined intruder might attempt to gain entry by removing the hinge-pins on one of the three exterior doors, allowing him to pull the door out of its frame. It won't work at Tech House. The hinges have a set of tabs and slots that lock when the door is closed. The door can't be opened or removed even if the pins are extracted.

However, the intruder would have difficulty getting as far as the doors or windows undetected, thanks to an Apollo spinoff called the Seismic Security Detector. Moonwalking astronauts deposited on the lunar surface a small, portable seismometer to record subsurface data regarding the moon's density and thickness. The experimental device is being adapted to such public-sector usage as law enforcement, grounds security, and wildlife research.



A Tech House extra—a tornado detector—is affixed by suction cup to the television set. Using the TV's electronics, it can detect a tornado within 18 miles, sound an alarm and cut it off automatically when the tornado passes.

At Tech House, the seismic detector is implanted in the lawn. A prowler's footstep will activate the device and start a sensing coil vibrating. The vibration generates a radio signal, which is picked up by a receiver in the house—it could also alert a police station—and the receiver emits an alarm burst.

There is still another security system, this one to protect against break-ins during sleeping hours or when the house is unoccupied. It consists of a number of intrusion detectors at the doors, windows, and beneath the carpets.

The detectors in the windows—for protection when the shutters are not locked in place—are wires woven into the screens. An intruder would have to cut or remove the screen to gain access through the window; if he did, he would set off a loud, siren-like alarm that would doubtlessly discourage further effort. The under-carpet detectors are pads which react to the pressure of a footstep and set off the alarm.

The security system's control box resembles the keyboard of a pushbutton telephone. Three such boxes are built into the walls at each of the outer doors and another adjacent to the master bedroom, for nighttime activation of the system. The home occupant retiring for the night or departing the house punches in a combination of numbers—otherwise his own footstep will trigger the alarm. A similar delay mechanism gives him 45 seconds to deactivate the alarm upon his return.

Topping off the security system is a safeguard against a lurking mugger when the occupant returns home at night. The heart of this system is an ultrasonic pen-sized transmitter: it is an outgrowth of the NASA—sponsored SCAN (Silent Communications Alarm Network) originally developed as an emergency warning system for schools. A press on the clip sends a signal which turns on the porch and yard lights from a distance of 30 feet.

All of that—and more—is Tech House, a fascinating collection of innovations that offer exciting prospects for the future.

The Langley home represents several years of effort on the part of a number of organizations. Sponsored by NASA's Technology Utilization Office, the project drew upon the support of NASA's field centers, the Department of Housing & Urban Development, the National Bureau of Standards, the Consumer Products Safety Commission, and Technology and Economics Inc. The National Association of Home Builders Research Foundation served as consultant to assure that the best modern materials and building practices were employed. Old Dominion University conducted housing-related research, and Hampton Institute experimented with optimum floor plan arrangements. The home's basic design is by the architectural firms of Forrest W. Coile & Associates and Charles W. Moore & Associates.

The window at left has thermal shutters, which are rolled up or down by a crank handle. When closed the Venetian blind-type shutters form an exterior window seal to keep heat in or out as desired.

Health care by remote direction, an automated disease detector, a voice-controlled wheelchair, a device that enables the blind to read almost anything in print—these are among a wealth of medical spinoffs being transferred from the world of aerospace to the public.

innovations in medicine

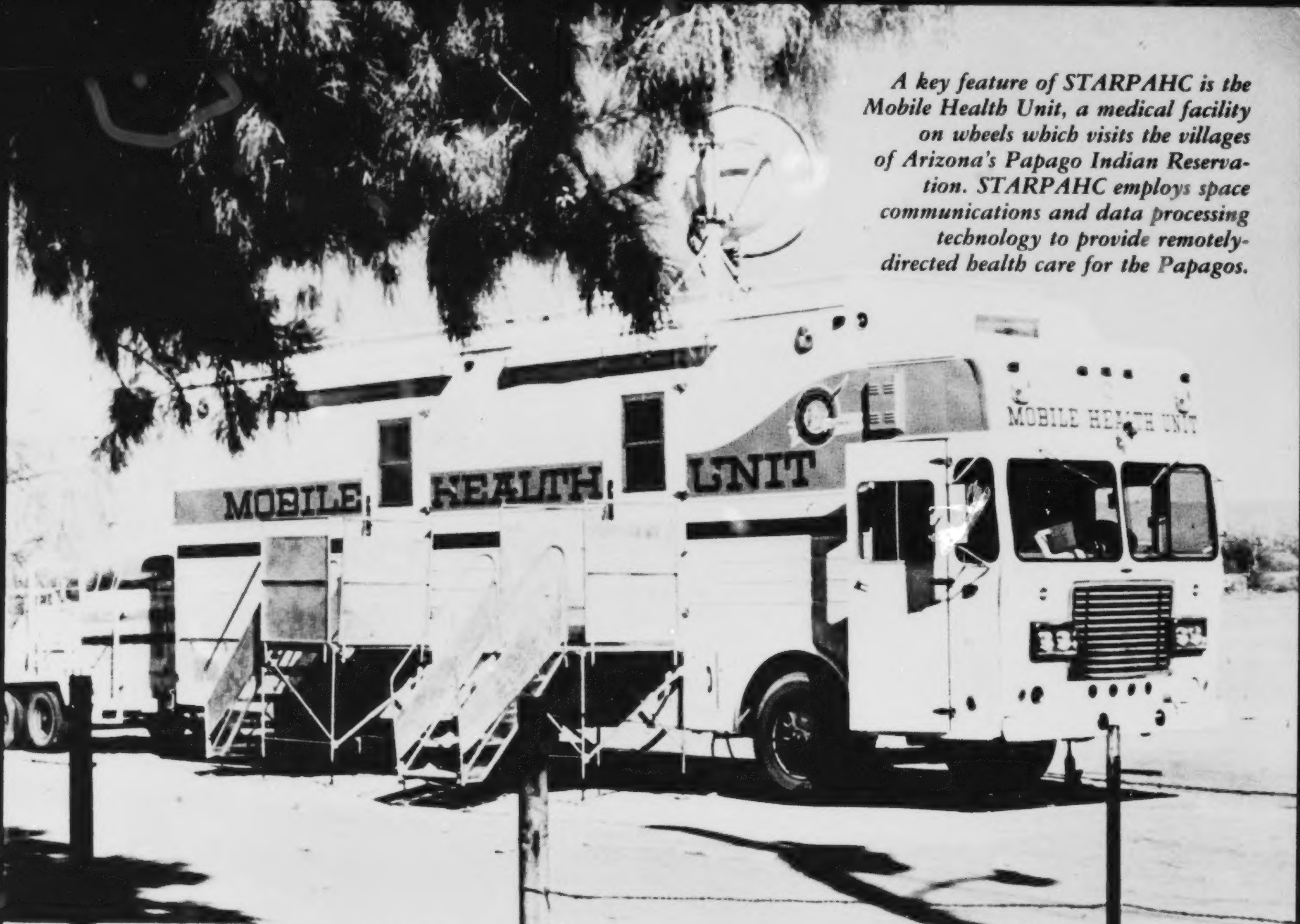
Ka Ka, Hickiwan, Vaya Chin, and Gu Vo sound like places in Southeast Asia. They are not; they are as American as Peoria. Villages of the Papago Indian Reservation in Arizona, they rank among America's most out-of-the-way places. As such they have benefited from a significant demonstration that applies space technology to provide health care to people in remote areas.

The demonstration has dual purposes. It is a developmental step toward meeting a future space requirement and at the same time it offers the potential of professional medical care to isolated populations whose access to regular medical service is inadequate or nonexistent.

NASA is planning now toward the day of long-duration flight—manned interplanetary missions for example—wherein routine health care and emergency treatment must be accomplished on-board the spacecraft over periods of months or perhaps even years. Since spacecraft design limits crew size, the medical assignment may be handled by a single astronaut-physician or by a crew member trained as a physician's assistant. In a space emergency demanding surgery, for instance, sophisticated communications equipment, backed by a computerized data processing system, would make it possible for a surgeon on Earth to "examine" the patient. He could study X-rays and other data, specify an in-flight surgical procedure, and guide the astronaut-medic step-by-step through the operation.

All over the world, millions of people live in areas almost as remote as astronauts in space. These people can benefit enormously from a system that enables a physician to help patients separated by great distances from his own physical location.

Such a system is being evaluated now. It is called STARPAHC (Space Technology Applied to Rural Papago Health Care). NASA technology in space communications and data processing is being applied to remote health services for the Papago tribe. STARPAHC is administered by the NASA Life Sciences Directorate in the Office of Space Sciences. It is a joint program involving NASA's Johnson Space Center, the Indian Health Service of the Department of Health, Education & Welfare, and the Papago's Executive Health Council. Lockheed Missiles & Space Co. is NASA's systems support contractor.



A key feature of STARPAHC is the Mobile Health Unit, a medical facility on wheels which visits the villages of Arizona's Papago Indian Reservation. STARPAHC employs space communications and data processing technology to provide remotely-directed health care for the Papagos.

The Mobile Health Unit's beat is the sparsely-vegetated, alternately flat and mountainous terrain of the Sonora Desert.

The Papago Indian Reservation is truly remote, lying in the Sonora Desert, an arid, sparsely-vegetated terrain, alternately flat and humped by clusters of mountains. Sprinkled over some 4,300 square miles are 75 villages where almost 10,000 people live. The principal Papago town of Sells is 70 miles from Tucson. Many of the villages are more remote, even from Sells, but distance is only part of the travel problem. Although there are some paved highways, many roads are unpaved, slow, and hazardous after heavy rains.

A key element in servicing the remote areas of the reservation is the Mobile Health Unit, a large van containing clinical equipment and the communications gear for contact with STARPAHC's base of operations, the Indian Hospital at Sells.

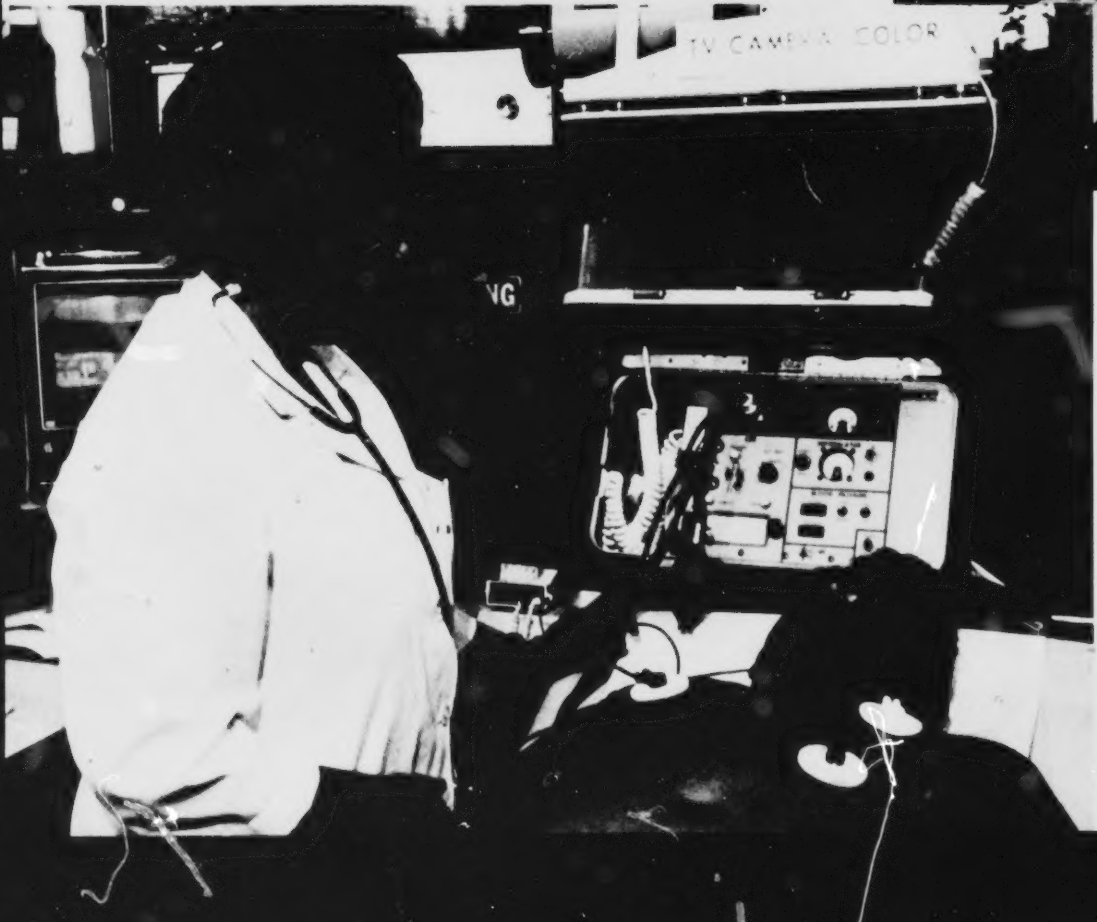
Operating on a pre-announced schedule, and staffed by a Community Health Medic (CHM) and a laboratory technician, the mobile clinic negotiates the rough roads of the reservation, visiting the villages in turn and handling as many as 27 patients daily.

In the van's reception room, the CHM interviews the patient as to complaint, symptoms, and other details. If necessary, the CHM can call up the patient's medical history from records stored in Albequerque by punching keys on a data terminal.

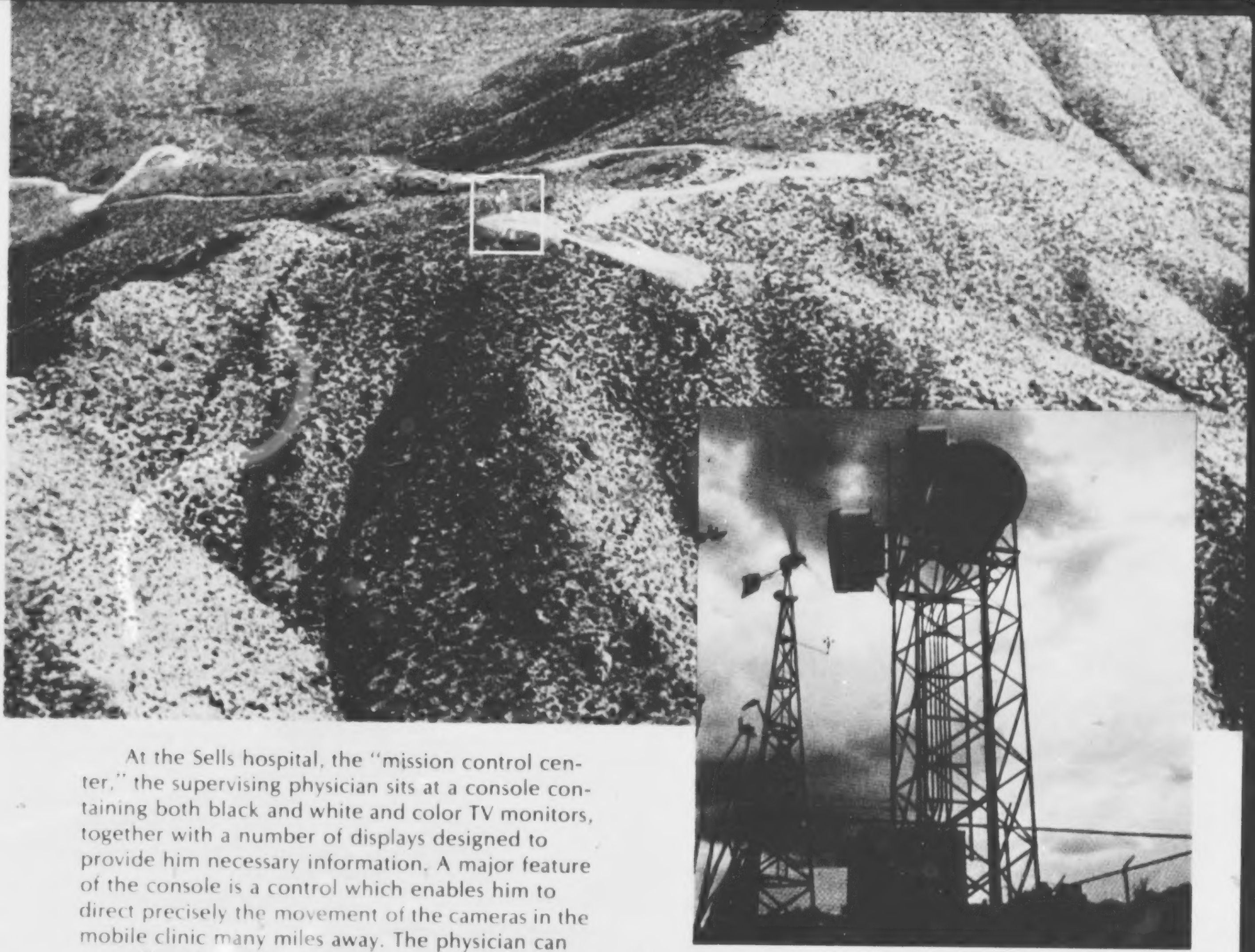
In the examining room, the CHM conducts the examination under the supervision of a physician at Sells, who may watch on TV and converse on the radio link. If the physician wants to view a particular part of the body, the CHM operates a color TV camera mounted overhead to transmit a close-up picture. When biochemical analysis is indicated, the laboratory room can handle a variety of tests and send the results immediately to the doctor as data or even as microscopic slides transmitted by TV. The mobile clinic can also transmit X-ray pictures.

A patient's medical history is displayed on a console instantly when summoned from stored records.

Supervising physician at Sells Indian Hospital can see, talk with and figuratively "touch" a patient in the Mobile Health Unit miles away.



In the Mobile Health Unit, a community health medic takes an electrocardiogram. TV camera (top), sends picture of the patient to the Indian Hospital at Sells, STARPAHC's base of operations. The electrocardiogram is also sent to Sells.



A major element of STARPAHC's space-derived telecommunications network is this microwave station on Quijotoa Mountain, near the center of the Papago reservation. The station relays TV, voice and medical data between the Sells hospital, the Mobile Health Unit and a fixed clinic in the town of Santa Rosa.

At the Sells hospital, the "mission control center," the supervising physician sits at a console containing both black and white and color TV monitors, together with a number of displays designed to provide him necessary information. A major feature of the console is a control which enables him to direct precisely the movement of the cameras in the mobile clinic many miles away. The physician can see, talk with and, in a figurative sense, "touch" the patient. With the equipment and information available to him, the physician can make timely diagnosis and specify treatment to be carried out by the CHM in the mobile van.

In addition to the Mobile Health Unit, STARPAHC includes a fixed clinic at Santa Rosa, another town within the reservation perimeter. This clinic, with a CHM, a lab technician, and administrative personnel, operates in the same manner as the mobile van, extending examination and treatment capability.

The STARPAHC network includes two other elements. At Albuquerque, a computer provides access to an established health information data base operated by the Department of Health, Education & Welfare. At the Indian Health Hospital in Phoenix, a staff of medical specialists can be called upon to consult with physicians at Sells when a unique or complex situation occurs.

The space-derived telecommunications network that makes possible this interchange has its focal point at the Sells Hospital. Atop Quijotoa Mountain, near the center of the reservation, a microwave station relays the TV and data signals between Sells, the mobile van, and the fixed clinic at Santa Rosa.

STARPAHC's community acceptance has been exceptional. Residents of the outlying villages depend on scheduled visits of the Mobile Health Unit and the daily services of the fixed clinic.

The system opens up a broad new potential for improving health care. The capability to communicate with remote villages suggests TV instructional programs in areas such as environmental health, sanitation, nutrition, and disease control. STARPAHC's initial success makes it likely that remote care activities will be continued upon conclusion of the two-year evaluation in mid-1977 when the Department of Health, Education & Welfare is expected to sponsor follow-on activities.

Space Stat-30 is a compact instrument which determines the sodium and potassium levels of a blood sample in just 48 seconds. It is a spinoff from NASA technology developed to monitor health of astronauts on long-duration missions.

New Diagnostic Aids

New methods of testing blood are among a variety of diagnostic tools brought forth by space research. As part of a program to develop techniques for astronaut health monitoring on long-duration flights, NASA contracted with Orion Research, Inc., Cambridge, Mass. to produce a compact blood analysis system. As spinoff from this work, Orion manufactures a pair of typewriter-size devices which simplify and speed blood analysis.

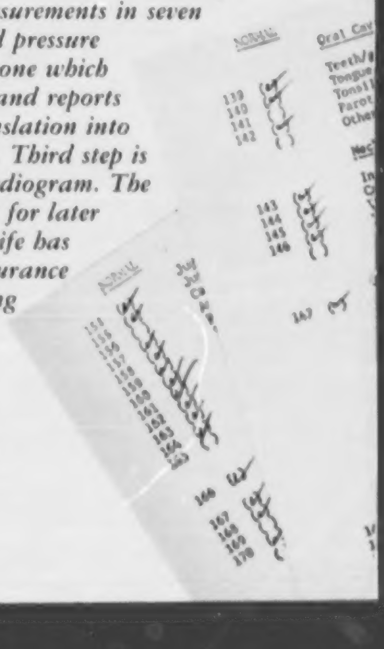
An important blood electrolyte, ionized calcium is necessary for blood coagulation, nerve function, and normal skeletal and cardiac muscle contraction. Earlier methods of measuring ionized calcium in blood were complex, requiring the use of highly-skilled technicians. Orion's development is a simply-operated, flat-bed box that makes ionized calcium determination a routine clinical test. It is called Space Stat-20 (the "Stat" is from the Latin statim, meaning "immediate.")

A very small blood sample—less than a milliliter—is injected into the machine where an electrode converts the ionized calcium concentration directly into an electrical signal. In less than three minutes, the value appears on a digital display. The device uses whole blood, making it unnecessary to extract the serum from the blood. Its speed of operation is important where rapid analysis is essential—during surgery, for instance. The companion system is Space Stat-30, which determines the sodium and potassium levels of a whole blood sample in just 48 seconds.

Gemeni, a new chemical testing instrument, can determine a broad range of blood components. Latest of a family of miniature centrifugal analyzers produced by Electro-Nucleonics Inc., Gemeni was developed originally for the Energy Research & Development Administration and for NASA's space shuttle.

Gemeni can handle 20 blood samples simultaneously. Punch-card programmed, it can make 12 tests of each sample to determine such values as blood sugar, calcium, cholesterol, albumin, glucose, uric acid, and other constituents. It can accomplish in 30 seconds tests that would take 15 to 20 minutes by manual methods. The first working model was installed in a U.S. hospital last year.

General Electric Company's Medical Data Acquisition Unit allows a seven-minute physical examination—no disrobing and no physician needed. The examination is a three-step process. Unit at left automatically records weight and measurements in seven seconds. In photo, blood pressure cuff contains a microphone which detects pressure sounds and reports them to console for translation into blood pressure readings. Third step is an automatic electrocardiogram. The console records all data for later analysis. Metroplitan Life has 200 units and other insurance companies are evaluating the system, a spinoff from GE's experience in biological telemetry acquired as contractor for NASA's Biosatellite program.



Check no or yes for the hist
blank If not asked or not d
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Give narrative description i

NO

General

2 (✓) Weight change
3 ( ) Fever/chills
4 ( ) Night sweats
( ) Other

Endocrine System

5 ( ) Heat/cold intoler
6 (✓) Thyroid problems
7 ( ) Family history di
8 (✓) Family history th
9 (✓) Neck surgery/irrad
( ) Other

Eye

10 (✓) Visual dysfunction
( ) Other

Ear, Nose, Throat

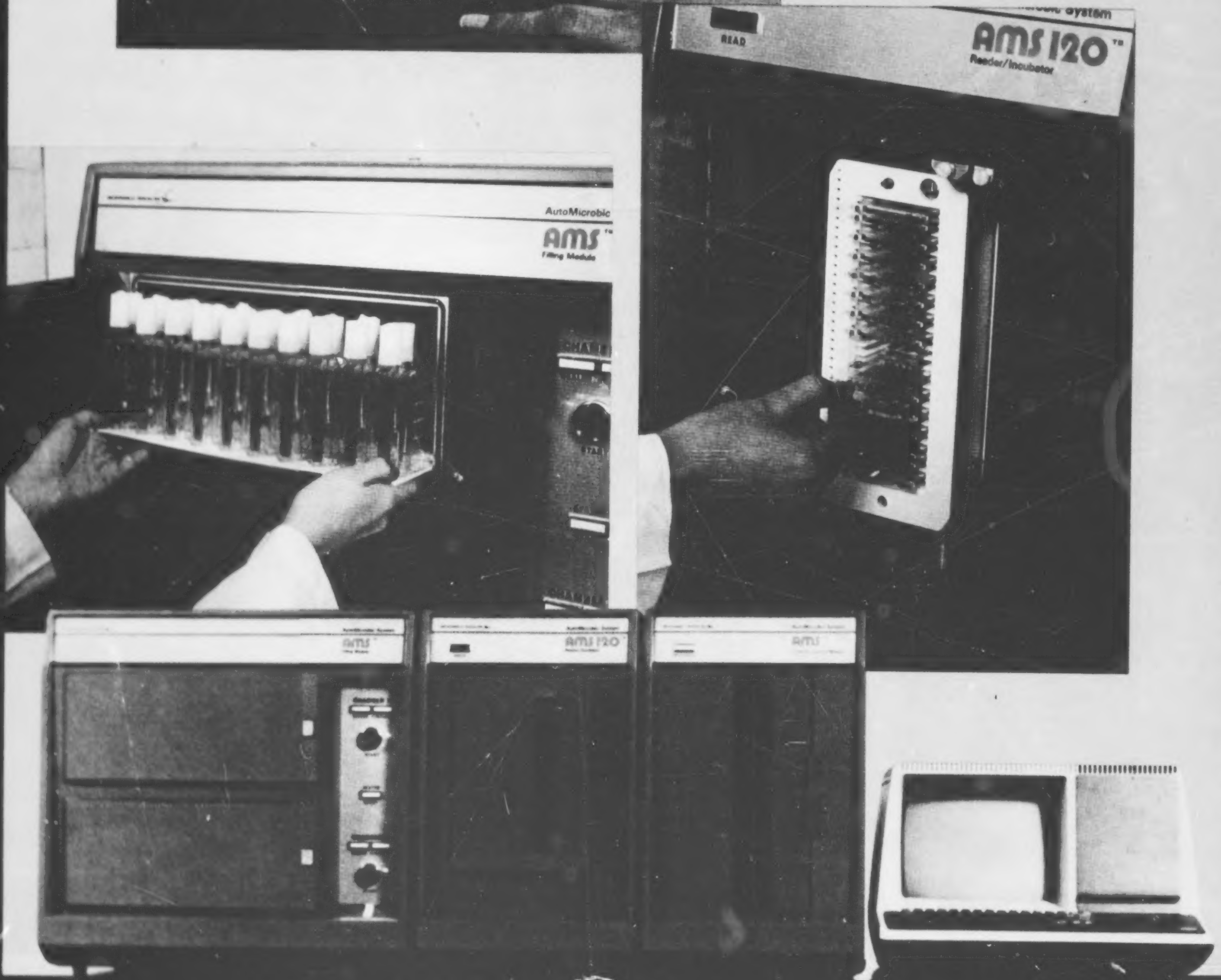
11 (✓) Difficulty hearing
12 (✓) Tinnitus
13 (✓) Epistaxis
14 ( ) Hoarseness
15 ( ) Sinusitis
16 (✓) Vertigo
( ) Other ( )

Gastrointestinal System

17 (✓) Nausea/retching ( )
18 (✓) Vomiting ( )
19 (✓) Hematemesis ( )
20 (✓) Dysphagia ( )
21 ( ) Indigestion (✓)
22 ( ) Heartburn (✓)
23 (✓) Abdominal pain ( )
24 (✓) Abdominal swelling ( )
25 (✓) Jaundice ( )
26 (✓) Hematochezia ( )
27 (✓) Melena ( )
28 ( ) Diarrhea (✓)
29 (✓) Constipation
30 (✓) Hernia
31 ( ) Hemorrhoids
32 (✓) Peptic ulcer disease
33 (✓) Gastrointestinal surgery
34 (✓) Gallbladder disease
35 (✓) Pancreatitis

A NASA computer program for monitoring the health status of astronauts served as a departure point for development of an automated medical data system. The Medical Information Management System (MIMS) permits a hospital to maintain up-to-date medical records for patient diagnosis and treatment. It also provides a large, readily available data base for medical research. With MIMS, doctors and aides can call up the record of a specific patient in seconds or search for specific data in the computerized file. MIMS was developed by NASA's Goddard Space Flight Center in cooperation with Lincoln University, Federal City College and Howard University Medical School. The system is commercially available from United Computing Systems Inc., Falls Church, Virginia.

The AutoMicrobic System (AMS) is a fully-automatated system which detects harmful micro-organisms in the human body, identifies them and determines which microbe-killing agents would be most effective in eliminating them. AMS originated in a NASA study. Samples of body fluids are placed into the AMS where they are exposed to nine different microbe nutrients. The AMS automatically monitors which cultures grow and therefore which pathogens were present in the fluid sample.


AutoMicrobic
AMS
Filling Module
READ
AMS 120
Reader/Incubator
AMS
AMS 120
AMS

Microbe Detector

Space science has contributed an advance to microbiology in the detection of harmful microorganisms, or pathogens, in body fluids. In the traditional manual method of testing for pathogens, specimens are prepared in cultures which are, in effect, "food" for specific microbes. The cultures are incubated for two to three days and studied for cell growths indicating the presence of disease-producing organisms. This process of incubation, detection, and interpretation now can be done automatically.

The AutoMicrobic System (AMS) represents years of intensive research and development by McDonnell Douglas Corp. that originated with a NASA study aimed at development of a fully automated microbial detection and identification system for spacecraft use. A urine specimen is placed into the system, where it is subjected to different freeze-dried microbe nutrients for the nine most common pathogens. An electro-optical scanner studies each specimen once an hour through a 4-to-13 hour cycle, operating automatically. Changes in cell growths on each culture are monitored by computer. The presence of pathogens is indicated when growth reaches a predetermined level.

The system also enumerates the pathogens and specifies the type. Developed initially to handle urine testing, AMS soon is expected to allow analyses of blood, spinal fluid, and other body fluids.

An additional capability under development is "susceptibility testing," or the determination of which microbe-killing agents—such as penicillin or other antibiotics—would be most effective in eliminating the pathogens. The whole process of detecting, identifying, and enumerating the pathogens and determining susceptibility is accomplished in less than half the time required for the manual procedure. On pushbutton command, results are printed or displayed on a screen.

The AMS minimizes human error, reduces technician time, and increases laboratory output. In cooperation with six leading microbiology laboratories, McDonnell Douglas and the marketing firm, Fisher Scientific Co., are conducting studies to compare data derived from the system with tests obtained by traditional manual methods. The Food & Drug Administration's approval of the susceptibility-testing procedure is pending.

Bone blocks underlying tissues, making it difficult to get clear x-rays of soft body tissues. A promising improvement: use of filters, such as those employed on the Landsat Earth resources satellite, to block out bone and enhance the soft tissue image. NASA's Goddard Space Flight Center is adapting Landsat technology to x-ray usage.

Space Imaging in Medicine

Space imaging techniques can have important applications in diagnostic medicine: getting clear X-ray images of soft parts of the body is difficult because they are blocked by bone. An example: early detection of lung cancer is vital but often difficult because, in the X-ray picture, the bone structure of the rib cage obstructs the view of the underlying lung tissue. To get a better picture of soft tissue, radiologists use internal dyes and radioactive substances, but these methods do not always produce good results, and they can be uncomfortable for the patient.

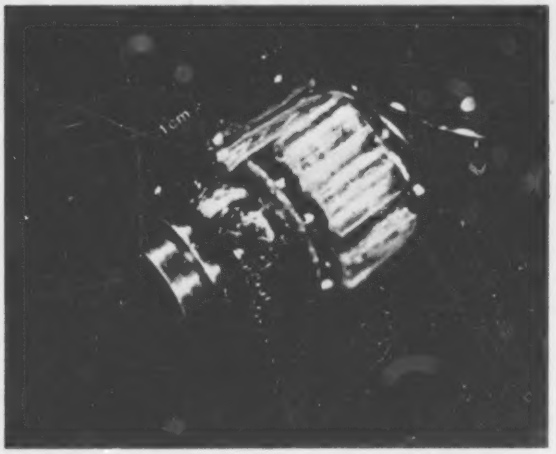
A promising improvement in soft-tissue imaging utilizes filters such as those employed on NASA's Landsat Earth-resources satellite. Landsat images can be filtered so that a specific area of interest shows up prominently and other areas are subdued. Landsat

NASA is developing a means for detecting hardening of the arteries by measuring arterial pulse waves. A "non-invasive" pulse sensor, affixed externally, eliminates the need to penetrate the skin. The sensor is an aerospace spinoff, as are other elements of the arterial pulse wave detector.

can be instructed, for instance, to survey a wheat crop. The wheat would appear in a designated color, the non-pertinent background down-played. The resulting image corresponds roughly to a newspaper's political situation map in which the significant areas are shaded.

NASA's Goddard Space Flight Center is adapting these image-processing techniques to X-ray usage. The simple and inexpensive system consists of a filter and an optical decoder developed by NASA. The filter is placed between the patient and the X-ray apparatus. Using the lung-cancer example, the filter blocks out the bone and the optical equipment displays a clear picture of the lung tissue.

A transducer originally used to measure air pressure in aircraft wind tunnel tests is the basis for a development important in diagnosis and treatment of certain types of brain damage. A totally implantable device, the intracranial pressure monitor measures and reports brain pressure by telemetry.



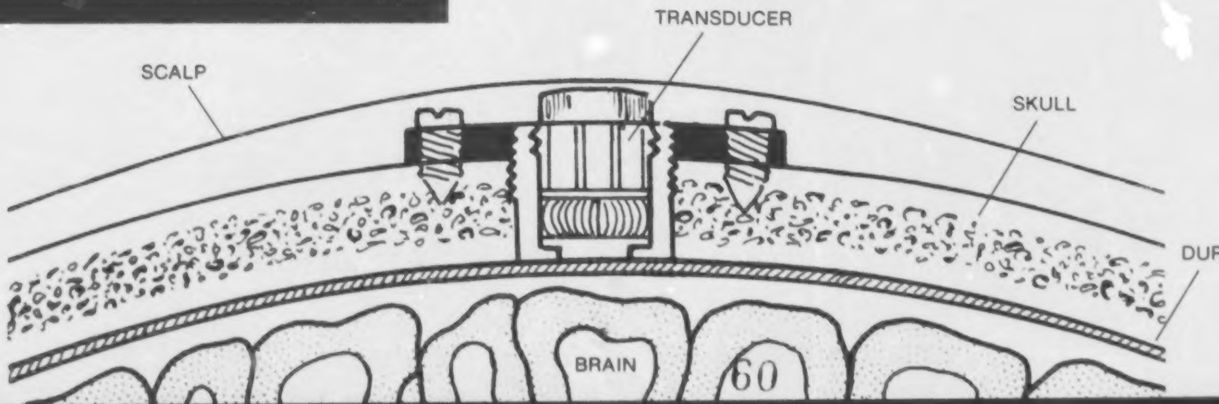
Brain Pressure Monitoring

Another type of aerospace sensory device offers promising application in diagnosis and treatment of brain damage caused by increased pressure.

Brain damage can result from external injury, as in an auto accident, or internal injury, as in stroke, infection, or tumor. Hydrocephalus, a condition occurring in infancy where an accumulation of fluid within the cranium causes enlargement of the head, is another cause of brain damage. In all these cases, brain damage is largely attributable to increased intracranial pressure, or ICP. Both medical and surgical techniques exist for controlling ICP, but there is widespread need for accurate and continuous information on the degree of pressure.

In current methods, the information can be obtained by drilling a hole in the skull and inserting a catheter, a flexible plastic tube connected to an external pressure-measuring instrument. This method has limitations: the catheter is a source of infection, movement of the subject is restricted, and there are problems with the reliability of the measurements because the catheter may become blocked by shifts in brain tissue.

NASA's Stanford Biomedical Application Team identified the problem and located applicable NASA technology. NASA-Ames and physicians at Stanford University then conducted extensive bench testing and animal studies of various implantable devices for



monitoring ICP. The most promising solution is a sensor originally developed at Ames Research Center for measuring air pressure over an airfoil in wind tunnel tests of aircraft. It is an inductively powered capacitive transducer—that is, a sealed pressure-measuring cell that reports ICP by telemetry.

The ICP monitor has a number of advantages. It is "minimally invasive," meaning that, while penetrating the skull, it does not penetrate the dura, the tough membrane that forms a protective cover around the brain tissue. Once implanted, the scalp is closed over the transducer, reducing risk of infection and allowing the patient freedom of movement. Most important, the monitor can report continuously with a higher degree of accuracy than is currently obtainable.

A program to validate the ICP monitor is under way and the system then will be evaluated on neurosurgical patients. Konigsberg Instrument Co., Pasadena, Cal. is producing pre-production ICP monitors for test and evaluation.

Liquid-Cooled Garment

Because there is no atmosphere to impede the sun's rays, it gets pretty hot on the moon—up to 250 degrees F. For that reason, astronauts working on the lunar surface wore a special suit consisting of a nylon outer layer supporting an inner network of tubing. Cool water flowing through the tubes kept the moonwalker comfortable. Researchers at NASA-Ames have made advancements in the Apollo suit design that offer highly efficient temperature control, and they have applied this technology to development of a water-cooled, brassiere-like garment used to aid the detection of breast cancer.

Cancerous tissue gives off more heat than normal tissue and this forms the basis for a cancer-detection technique known as infrared thermography. However, it has been difficult to interpret thermograph results for detecting cancer in its earliest stages.

The liquid-cooled bra, being evaluated by the Breast Cancer Detection Demonstration Center in Oklahoma City, cools the breast to improve resolution of the thermograph image. Cancerous tissue recovers from cooling faster than normal tissue because of the increased blood flow characteristic of cancerous tumors. By increasing the temperature difference between normal and cancerous tissue through cooling, the differentiation becomes more apparent on the thermograph. The NASA-Ames bra contains tubes which carry the water to and from a pumping refrigeration unit.

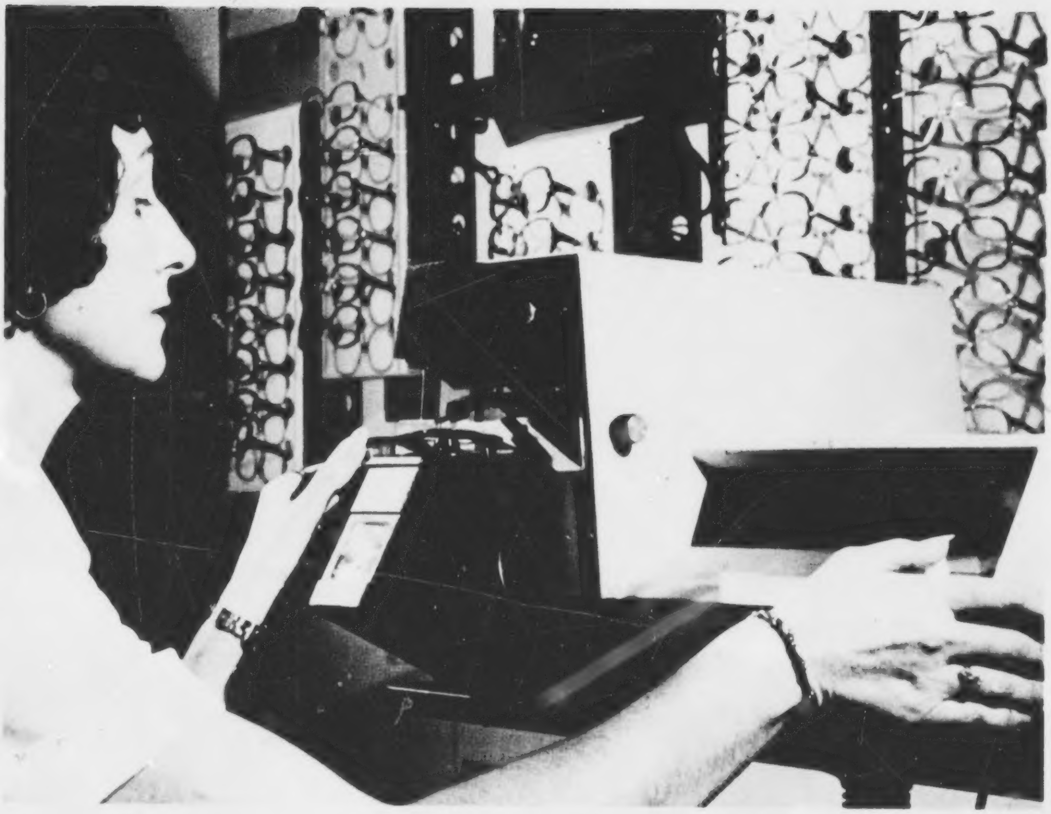
A liquid-cooled bra, offshoot of Apollo moon suit technology, aids the cancer-detection technique known as infrared thermography. Water flowing through tubes in the bra cools the skin surface to improve resolution of thermograph image.

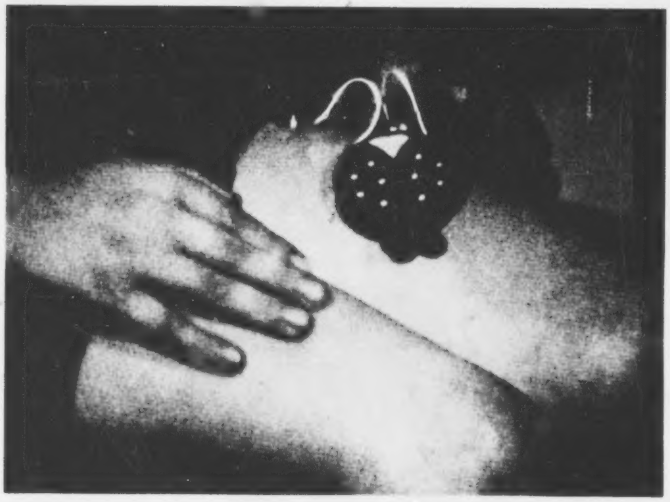
Help for Crippled Children

Children with cerebral palsy have nervous system defects which lead to muscular spasticity and loss of coordination. Many of these children have great difficulty walking because certain muscles are in a constant state of contraction.

Surgical techniques can lengthen muscles or tendons to improve the child's walking pattern, but it is vital to diagnose accurately the particular spasticity problem of each patient; the individual muscles causing the handicap vary greatly from child to child. It is difficult by physical examination alone to determine precisely which muscle groups are most involved. Biotelemetry has provided a solution. For the past two years, the Children's Hospital at Standord, assisted by NASA and the Stanford Biomedical Application Team, has been applying biotelemetry to the cerebral palsy problem.

Auto-Lensmeter is an automated optician's aid which measures the corrective prescription ground into eyeglass and contact lenses in a fraction of normal time. The lens is positioned on a mount, the operator presses a button, and in two seconds the results appear in standard prescription form, on a digital display or on a printed record. Produced by Acuity Systems, Inc., Reston, Virginia, Auto-Lensmeter is a companion to the company's first product, the Auto-Refractor eye-testing instrument. The latter was developed by a Stanford Research Institute employee who worked on an infrared optometer for NASA's Ames Research Center.





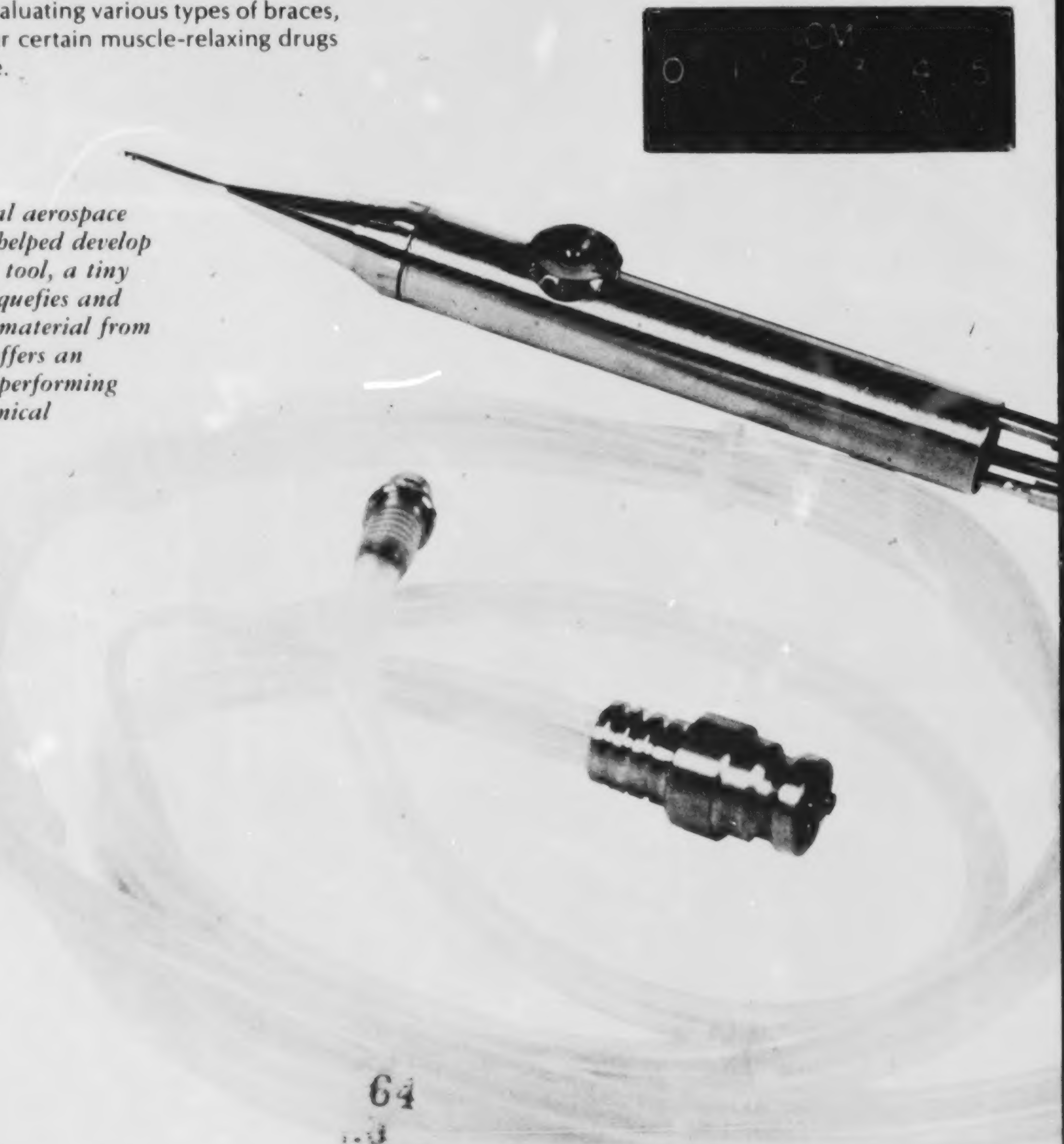
Space biotelemetry—physiological signals sent by radio waves—is being applied to diagnose accurately spasticity in children crippled by cerebral palsy. Miniature sensor/transmitters affixed on legs send wireless data on muscle activity helpful in determining corrective surgery and other remedial measures.

Used extensively throughout the space program to observe astronaut vital functions from the ground, biotelemetry is the monitoring of physiological signals sent by radio wave. In the cerebral palsy application, the signal is the "EMG"—for electromyogram—which indicates the activity of the leg muscles. Biotelemetry's advantage is that it needs no wires; other methods of monitoring EMG involve wires connecting a sensor on the patient to a recorder, thus interfering with the subject's normal walking pattern.

Freedom of movement is very important to the child with cerebral palsy, who frequently has an impaired sense of balance and lacks the muscle control necessary to protect himself when he falls. Telemetry offers a means for unencumbered recording of the child's true gait pattern, information extremely helpful to the physical therapist and the orthopedic surgeon in determining the need for corrective surgery, evaluating various types of braces, and deciding whether certain muscle-relaxing drugs might prove effective.

With the help of L&M Electronics Co., Daly City, Cal., NASA and Children's Hospital at Stanford introduced an improvement which eliminates the waist pack and the connecting cables previously used. Miniature transmitters, about the diameter of a half dollar, are affixed directly over the muscle group being studied. Each transmitter has its own battery and a pair of sensing electrodes. Because they are small and lightweight, several transmitters can be used to broadcast EMG signals from both legs simultaneously.

This important advance is now in active use by the Children's Hospital at Stanford for the cerebral palsy application. It appears to have broader potential, because it could be used for monitoring other types of physiological signals where biotelemetry offers clinical advantage.



Drawing upon several aerospace technologies, NASA helped develop this cataract surgery tool, a tiny cutter-pump which liquefies and pumps cataract lens material from the eye. The design offers an improved method of performing cataract surgery. Clinical testing of the device is underway.

Cataract Surgery Tool

A cataract is a condition in which the lens of the eye becomes opaque, restricting vision and leading to potential blindness. Surgery to remove the cloudy material is necessary to restore vision. More than 400,000 people a year need such surgery in the United States alone. Traditional surgical technique requires a 180 degree incision, and then numerous stitches to close it. Since the possibility of infection is high, patients are kept in the hospital 10 days after surgery.

Seeking to improve this technique, Cleveland eye surgeon Dr. William J. McGannon, the Retina Foundation of Boston, and NASA-Lewis joined to apply advanced technology in the fields of fluid mechanics, high-speed rotating machinery, miniature mechanisms, pumps, seals, and bearings.

The resulting NASA-McGannon cataract surgery tool is a tiny cutter-pump which liquefies and pumps the cataract lens material from the eye. Inserted through a small incision in the cornea, the tool can be used on the hardest cataract lens. The cutter is driven by a turbine which operates at about 200,000 revolutions per minute.

Incorporated in the mechanism are two passages for saline solutions, one to maintain constant pressure within the eye, the other for removal of the fragmented lens material and fluids. Three years of effort have produced a design, now being clinically evaluated, with excellent potential for improved cataract surgery. The use of this tool is expected to reduce the patient's hospital stay and recovery period significantly.

New Help for the Sightless

Duke Lumsden operates a candy shop in Tacoma, Wash. Duke is blind, yet he has no trouble differentiating between the values of currency he handles in the course of business. He is aided by a spinoff from space-developed optical-electronic scanning technology known as the Paper Money Identifier. The PMI is manufactured by EMR Ltd., Los Angeles.

Duke Lumsden, blind concession operator in Tacoma, Washington, can identify denominations of American bills with the help of his Paper Money Identifier. The device is a spinoff from space-developed optical-electronic scanning technology.

This blind child is reading, thanks to a device called the Optacon. The boy is passing a mini-camera over a printed page with his right hand: with his left he is sensing a vibrating image of the letters the camera is viewing. The Optacon allows the blind to read almost anything in print, not just braille transcriptions. The system originated in research performed at Stanford Research Institute under NASA sponsorship.

It's not distinguishable by the human eye, but each denomination of American currency has a unique distribution of colors. This fact enables the PMI to tell the difference between different denominations of paper money.

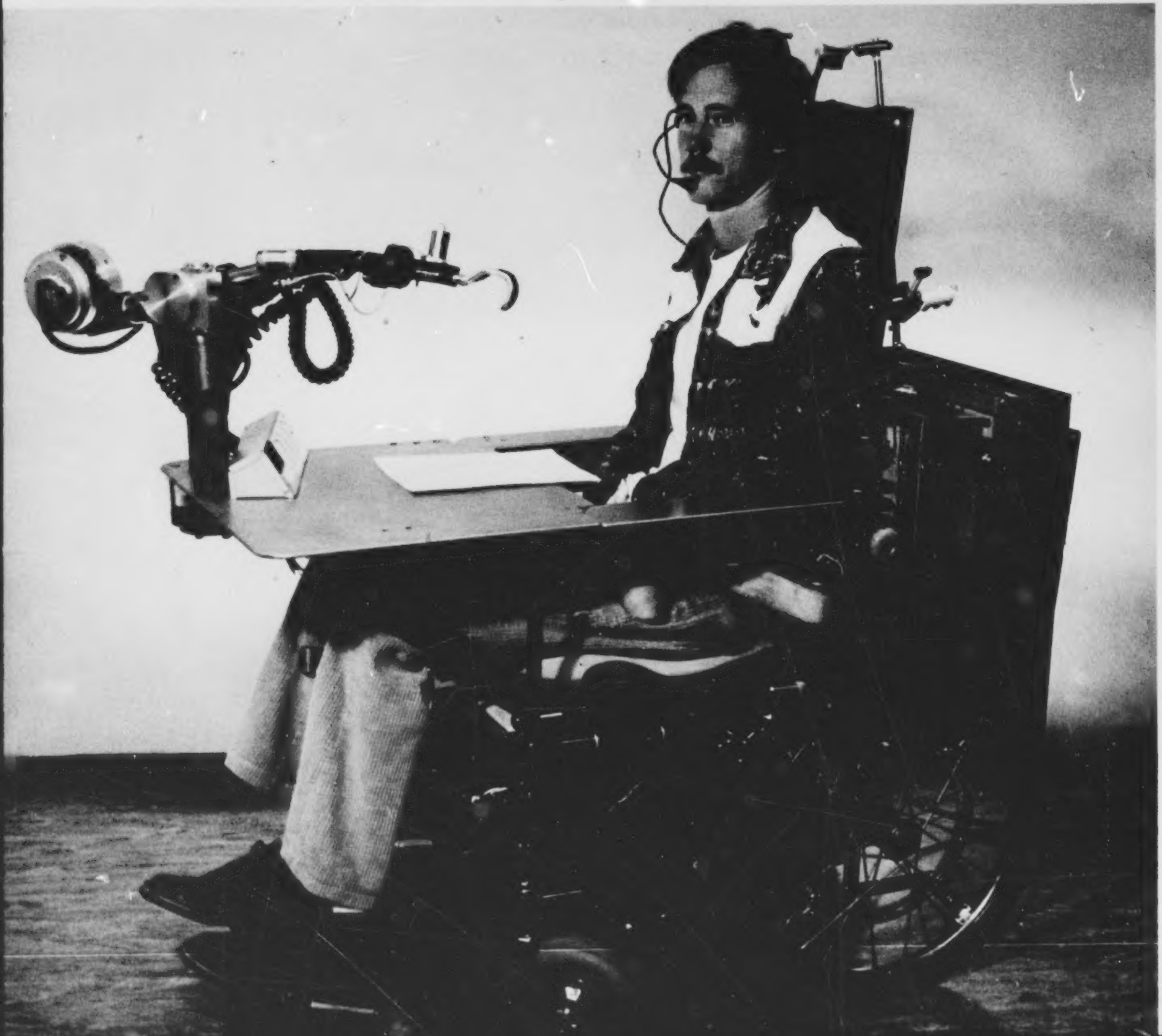
The device, the size of a cigarette pack, emits a narrow beam of invisible infrared light. This beam reacts to the reflectivity of the colors on the bill and causes an oscillator to generate an audible signal. As Duke passes his PMI lengthwise along the back of a bill, he hears a distinctive series of tones that identifies each denomination.

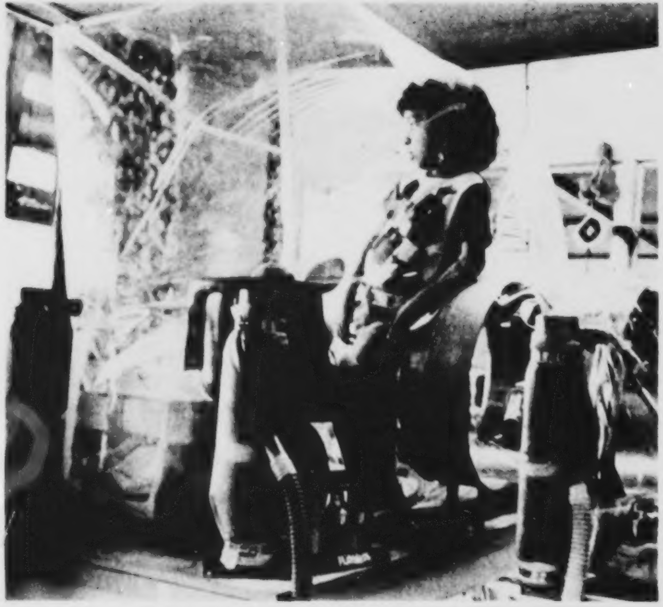
Duke Lumsden is very pleased with the paper money identifier, which he got through Tacoma's Technology Transfer Center. He not only handles paper money with ease, but he has discovered another use for the device. Before receiving the PMI, he had difficulty operating his tape recorder because he couldn't determine which track the tape was using; now his PMI tells him, by reacting to the different colors on the switch button light.

Thanks to another aid to the sightless called the Optacon, a blind person may be reading this printed page. The Optacon is an important advance for the blind and the deaf-blind, because it permits them to read almost anything in print, not just braille transcriptions.

The concept behind the Optacon combined optical and electronic technology and incorporated research performed at Stanford Research Institute under NASA-Ames sponsorship. A newly-formed company, Telesensory Systems Inc., Palo Alto, Cal., then continued the development with assistance from Stanford University and funding provided by the Department of Health, Education & Welfare and the Office of Naval Research.

Michael Condon, a quadraplegic from Pasadena, California, demonstrates the NASA-developed voice-controlled wheelchair and its manipulator, which can pick up packages, open doors, turn a TV knob, and perform a variety of other functions. A possible boon to paralyzed and other severely handicapped persons, the chair-manipulator system responds to 35 one-word voice commands, such as "go," "stop," "up," "down," "right," "left," "forward," "backward." Heart of the system is a voice-command analyzer which utilizes a minicomputer. Commands are taught to the computer by the patient's repeating them a number of times; thereafter the analyzer recognizes commands only in the patient's particular speech pattern. The computer translates commands into electrical signals which activate appropriate motors and cause the desired motion of chair or manipulator. Based on teleoperator and robot technology for space-related programs, the voice-controlled system was developed by Jet Propulsion Laboratory under the joint sponsorship of NASA and the Veterans Administration. The wheelchair-manipulator has been tested at Rancho Los Amigos Hospital, Downey, California, and is being evaluated at the VA Prosthetics Center in New York City.





A Houston five-year-old known as David is getting a "space suit," a vitally important gift that will give him mobility he has never known. David suffers from a rare malady called severe combined immune deficiency, which means that he was born without natural body defenses against disease: germs that would have little or no effect on most people could cause his death. As a result, he has spent his entire life in germ-free isolation rooms, one at Houston's Texas Children's Hospital, another at his home.

The Optacon gets its name from OPtical-to-TActile CONverter. It works by converting regular inkprint into a readable, vibrating tactile form. The blind reader moves a miniature camera across a line of print with one hand while the index finger of the other hand is placed on the system's tactile array. As the camera moves over a letter, the image is simultaneously produced on a tactile array by small vibrating rods. The reading finger feels the enlarged letter as it passes over the tactile screen.

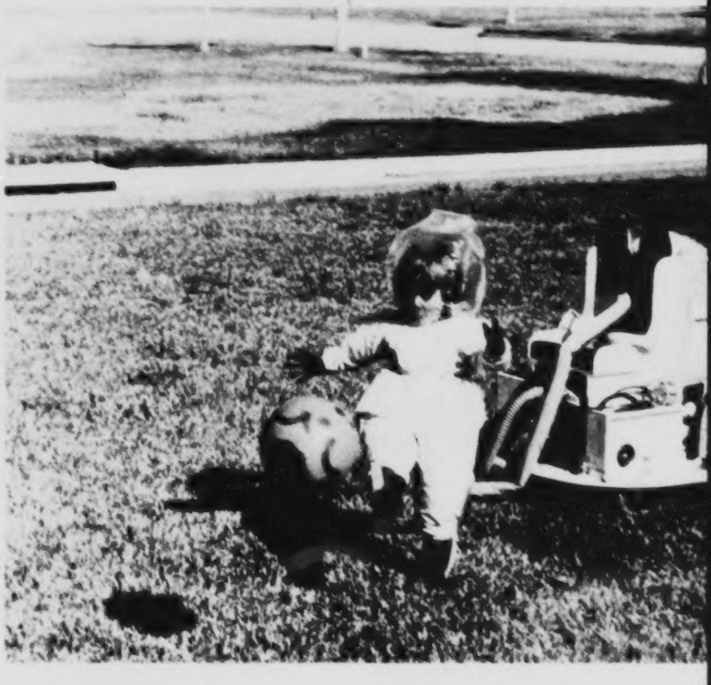
Telesensory Systems provides the training essential to master the Optacon. The standard course covers 50 hours in nine training days. Reading speed after training varies from student to student, the average being about 10 words a minute. After considerable practice, speeds of 40 words a minute are common and speeds as high as 90 words per minute have been achieved.

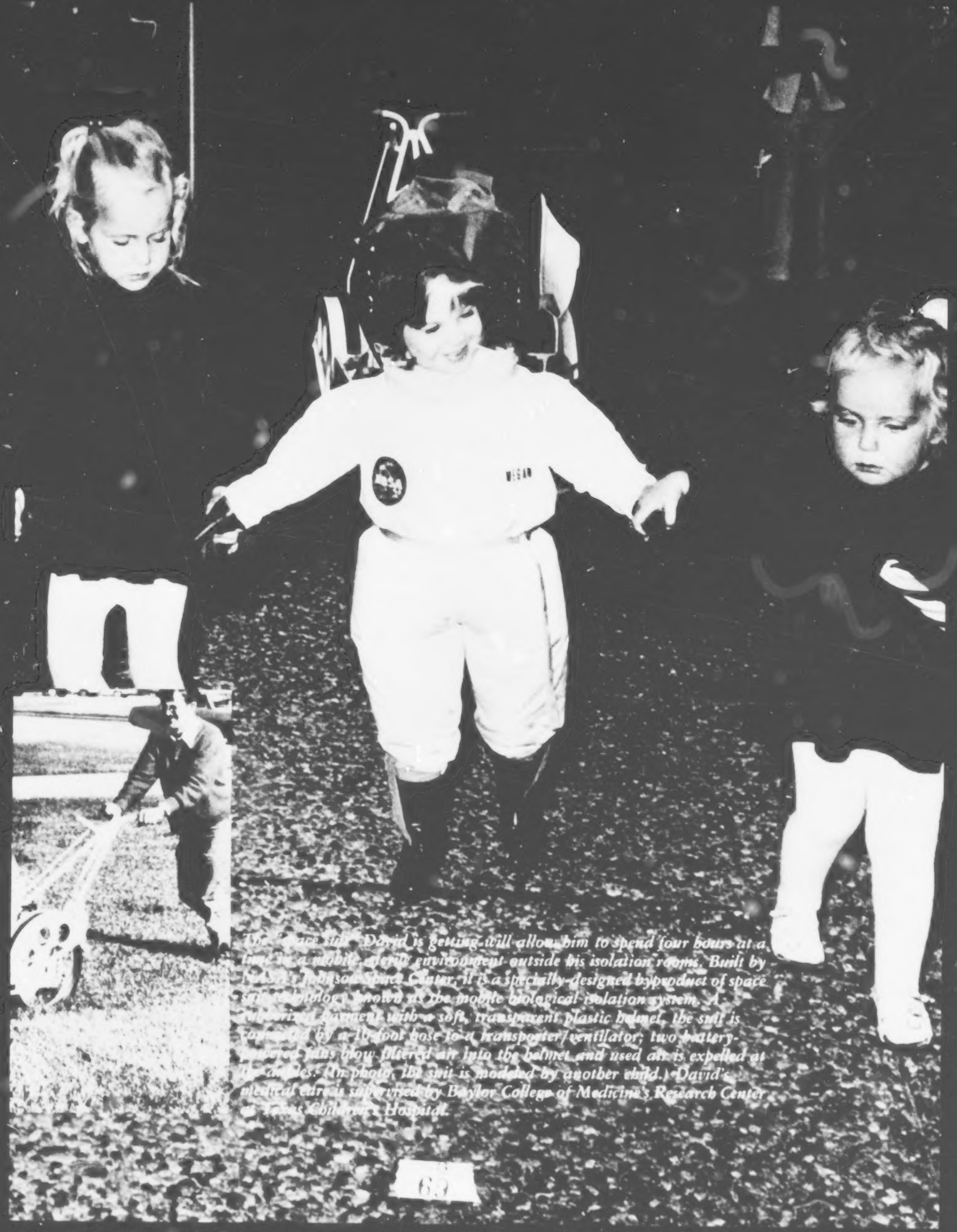
The Optacon opens up a whole new world for the blind, who are no longer limited to material that has been tape recorded or brailled. It enables them to carry out a great many everyday reading tasks.

For school use, the Optacon makes the instructional materials of the sighted available to the blind. It helps the sightless to obtain jobs, win promotions, and enter vocational areas once closed to them.

For example, a typewriter attachment permits a blind secretary to read what she is typing, to make corrections and to fill out printed forms. Another accessory allows a blind engineer or scientist to read the visual display of an electronic calculator.

The Optacon is one of the most dramatic examples of how technology transfer is improving the status of millions of people in all walks of life.





The space suit David is getting will allow him to spend four hours at a time in a mobile sterile environment outside his isolation rooms. Built by NASA's Johnson Space Center, it is a specially-designed byproduct of space suit technology known as the mobile biological isolation system. A pressurized garment with a soft, transparent plastic helmet, the suit is connected by a 10-foot hose to a transporter/ventilator; two battery-powered fans blow filtered air into the helmet and used air is expelled at the ankles. (In photo, the suit is modeled by another child.) David's medical care is supervised by Baylor College of Medicine's Research Center at Texas Children's Hospital.

A unique device for surveying forest lands highlights a number of spinoff developments benefitting environmental protection and resources management.

technology and the environment

The Forest Service has 187 million acres of land in 44 states and Puerto Rico. Accurately marking the boundaries of such extensive property is obviously a monumental task. The Forest Service once estimated that, with conventional surveying techniques, it would take 24 years and cost $100 million. But a NASA-developed system would enable the Forest Service to do the job in 10 years at considerable savings.

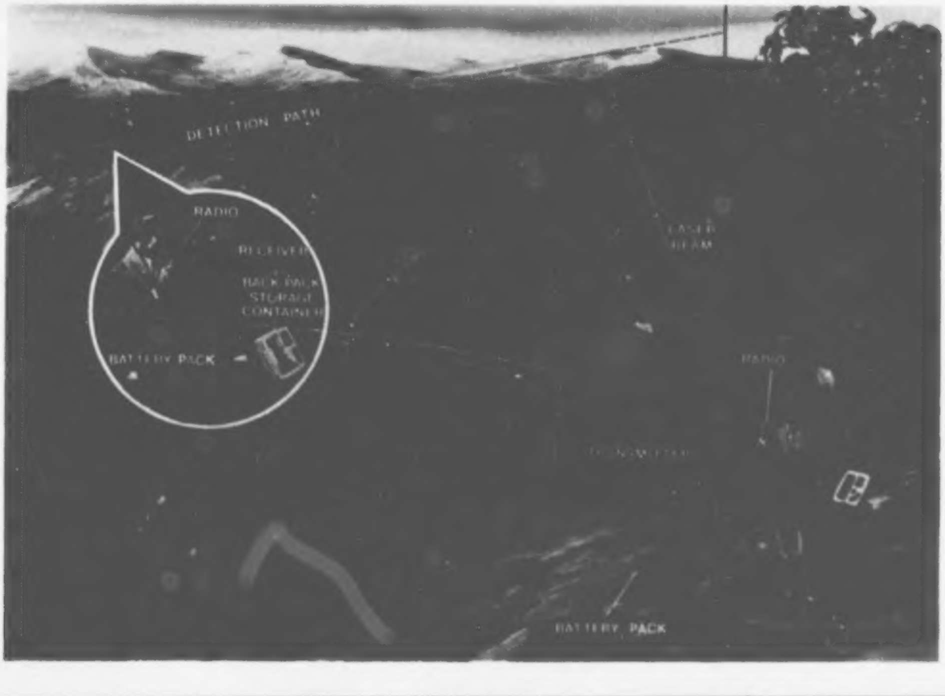
New emphasis on border-marking our national forests became necessary in recent years because of increasing use of nearby land by private owners, whose enterprises range from timber harvesting to resort development. A large percentage of forest land is not well enough located and marked to allow landowners to manage their properties with confidence that they are not trespassing.

The survey was originally estimated as a 24-year job because mountains, trees and thick bushes often block direct sighting between two points, the conventional method of surveying. Thus it was necessary to hack sighting paths through the forests by machete and bulldozer, a costly and time-consuming process.

Forest Service officials consulted NASA and found a solution in the application of laser technology originally developed for satellites. NASA-Goddard built a system called a "laser range pole," a portable battery operated back-packed device that allows direct sightings no matter how rough the intervening terrain or how thick the forest.

The equipment consists of a laser transmitter and a receiver. From a given property marker, the transmitter pulses a laser beam vertically, several thousand feet in some cases. At a second surveying point about a mile away, the receiver detects the laser pulse high above the trees, and locks in on the exact direction. Thus provided a bearing between the two points, a

A major problem in surveying 187,000,000 acres of Forest Service property is that trees and mountains block direct sightings. This NASA-developed "laser range pole" provided a solution. The receiver at left detects a vertically-fired laser beam (right) to get an accurate bearing between two points not visible to each other. Non-exclusive license to manufacture this device is available from NASA-Goddard.



ground crew can extend the border line back to the sending point by conventional surveying techniques.

After NASA developed the laser pole, a joint NASA-Department of Agriculture contract was awarded RCA Corp., Burlington, Mass., to produce an operational version. The Forest Service now has several in use. So does the Department of the Interior's Bureau of Land Management for surveying large areas such as those in Alaska.

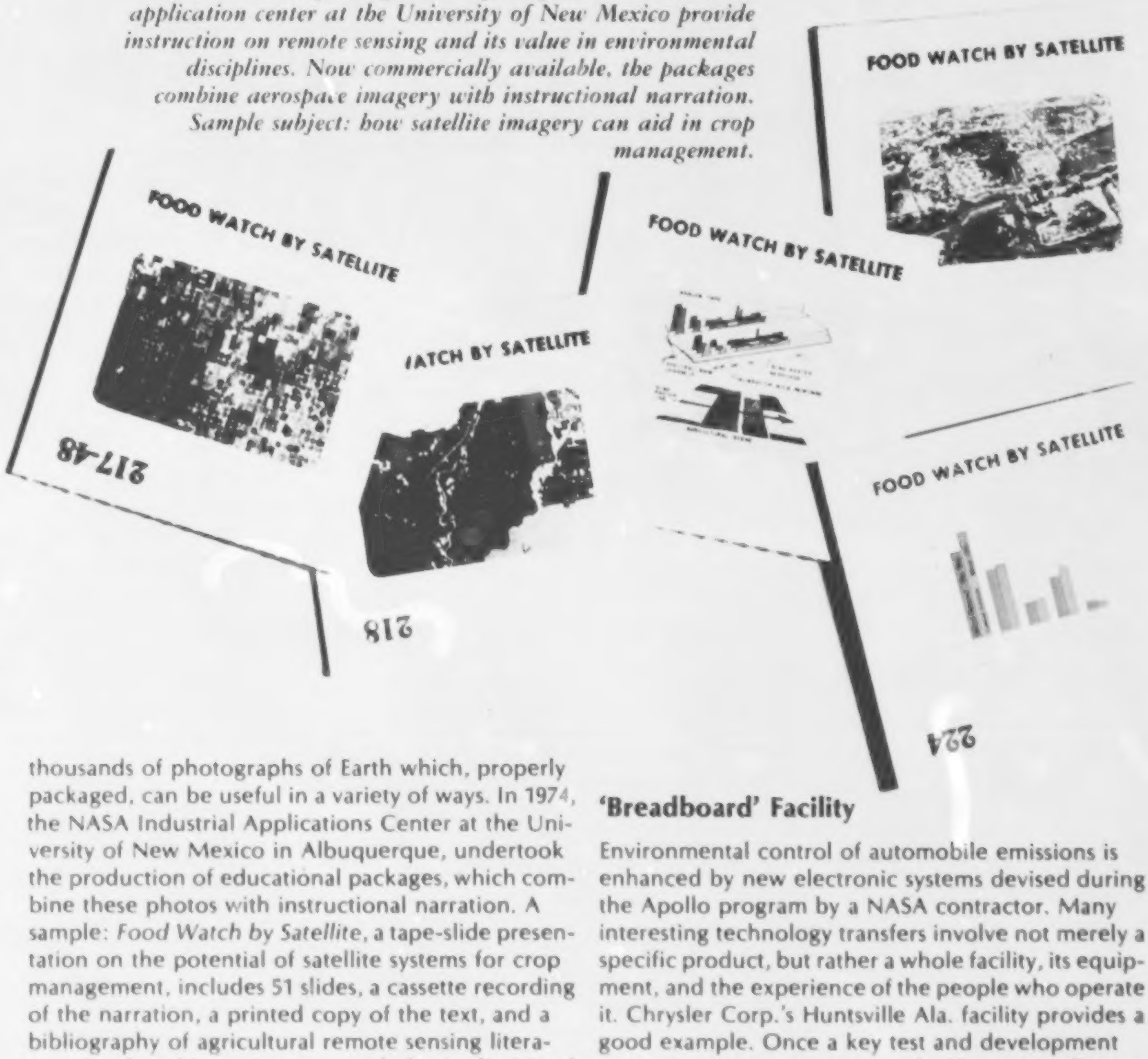
Educational Packages

An environmental spinoff for educational purposes broadens the availability of remote sensing imagery.

Through manned space missions, Landsat, and in aircraft remote sensing programs, NASA is acquiring thousands of photographs of Earth which, properly packaged, can be useful in a variety of ways. In 1974, the NASA Industrial Applications Center at the University of New Mexico in Albuquerque, undertook the production of educational packages, which combine these photos with instructional narration. A sample: *Food Watch by Satellite*, a tape-slide presentation on the potential of satellite systems for crop management, includes 51 slides, a cassette recording of the narration, a printed copy of the text, and a bibliography of agricultural remote sensing literature. Produced in conjunction with the Audio-Visual Institute, also of Albuquerque, the package now sells for $90.

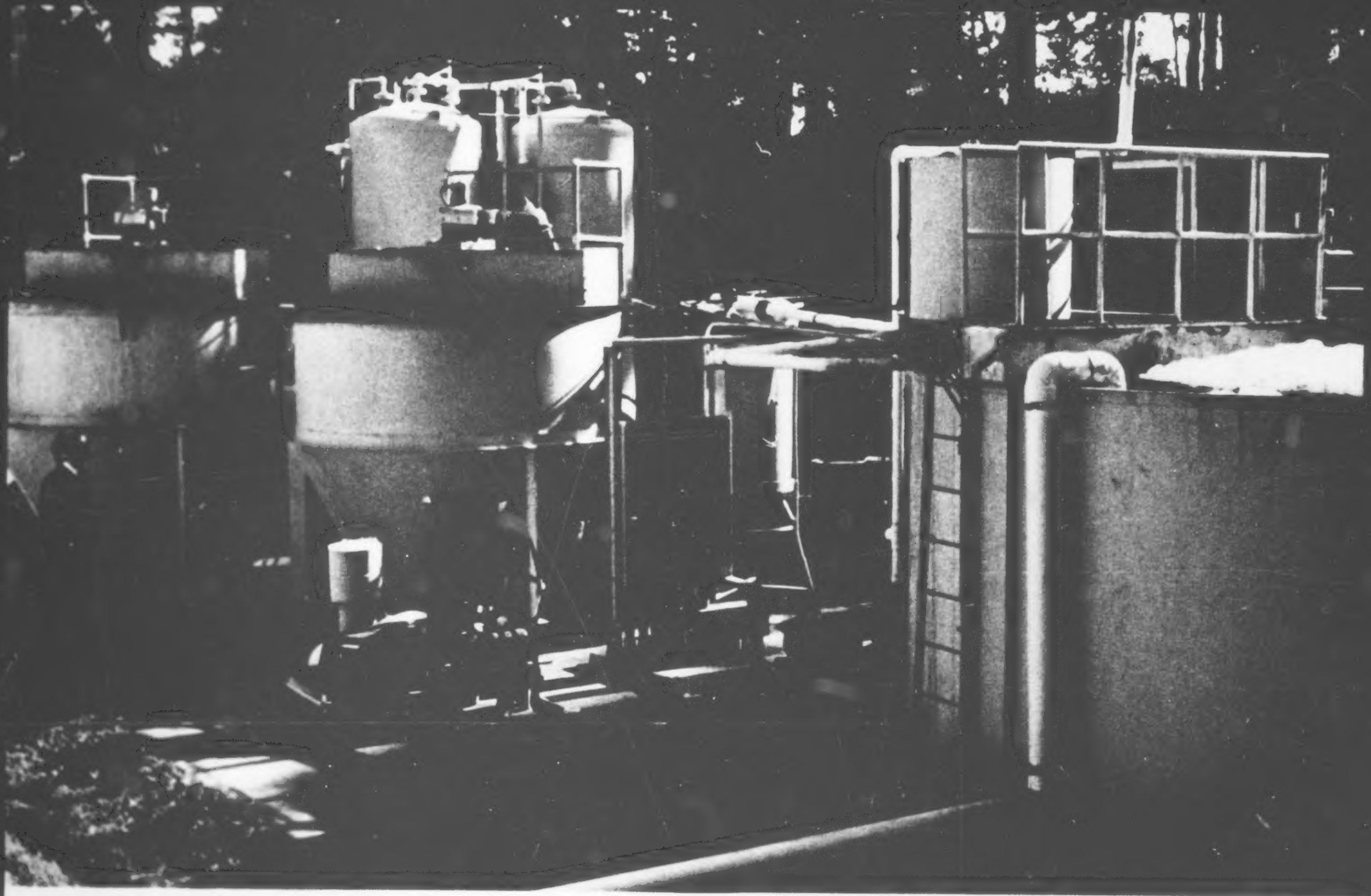
This and similar audio-visual presentations are being used by educational institutions for teaching how remote sensing can be applied to resource problems, or for adding perspective to existing courses in ecology, geography, geology and urban planning. Other users include artists, environmental centers, and consulting firms engaged in the preparation of environmental impact statements. The NASA Center in Albuquerque sold the production rights to a commercial firm, Pilot Rock Inc. of Arcata, Cal., which now offers 76 different educational packages.

Educational packages developed by NASA's industrial application center at the University of New Mexico provide instruction on remote sensing and its value in environmental disciplines. Now commercially available, the packages combine aerospace imagery with instructional narration. Sample subject: how satellite imagery can aid in crop management.



'Breadboard' Facility

Environmental control of automobile emissions is enhanced by new electronic systems devised during the Apollo program by a NASA contractor. Many interesting technology transfers involve not merely a specific product, but rather a whole facility, its equipment, and the experience of the people who operate it. Chrysler Corp.'s Huntsville Ala. facility provides a good example. Once a key test and development center for the space program, the Electronics division there is now engaged in similar but non-NASA work for the parent company.



In the sixties, Chrysler was NASA's prime contractor for the Saturn I and IB test launch vehicles. The company installed and operated at Huntsville what was known as the Saturn I/IB Development Breadboard Facility. "Breadboard," means an array of electrical and electronic equipment for performing a variety of development and test functions. This work gave Chrysler a broad capability in computerized testing to assure quality control in development of solid-state electronic systems.

Today that division is manufacturing many products not destined for NASA, most of them being associated with the company's automotive line. A major project is production and quality-control testing of the "lean-burn" engine, one that has a built-in computer to control emission timing, and allow the engine to run on a leaner mixture of fuel and air.

Other environment-related products include vehicle emission analyzers. The newest of the line is an accurate, portable solid state instrument for testing auto exhaust gases. The exhaust analyzers, now being produced for company dealers and for service

stations, are expected to find broad application in state and municipal auto inspection programs.

Similar technology is employed in production of other exhaust analyzers, including systems to check out new engines in laboratory tests and units for testing new car emissions to assure that they meet Environmental Protection Agency standards. The Automated System for Emission Testing (ASET) can coordinate as many as seven vehicle exhaust analyzers at one time. The Automotive Pre-Check Corp. of Los Angeles uses ASET to test about 3,000 new cars each year, to comply with California air pollution laws which require that a two-percent sample of all new cars sold in the state be exhaust-analyzed.

This Jacksonville, Florida, apartment complex has a wastewater treatment system which clears the water, removes harmful microorganisms and reduces solid residue to ash. It is a spinoff from spacecraft waste management and environmental control technology.

Two environment-related automotive products are Chrysler's "lean-burn" engine and an auto exhaust emission analyzer. These and other products now being built at the Electronics Division trace their lineage to technology acquired when it was a key test and development center for the space program.

Packaged Waste Treatment

As NASA contractor on the biosatellite program several years ago, General Electric Co. acquired experience in waste management and associated spacecraft environmental technology. The company has spun off this experience into packaged waste treatment systems for both sea and land applications.

GE's initial effort was a "shipboard waste treatment system," which used physical and chemical processes to clear wastewater, settle the solid matter, and remove harmful microorganisms. The solid residue is reduced to a small amount of ash by the system. GE built and installed these sludge incinerator systems on an Army dredge, a Navy destroyer escort and three Great Lakes steel ore carriers.

Shortly thereafter, passage of the 1972 Clean Water Act prohibited ships from dumping treated or untreated wastewater. Thus, demand turned from shipboard treatment systems to shipboard holding tanks and shore-based treatment systems.

Using the same technology, GE then built and tested a trial land-based system. This experiment evolved into an advanced 50,000-gallon-a-day "packaged waste treatment system," installed in Jacksonville, Fla. by Demetree Builders of that city. The system now serves about 600 units in the Villa del Rio and Ortega Arms apartment complexes.

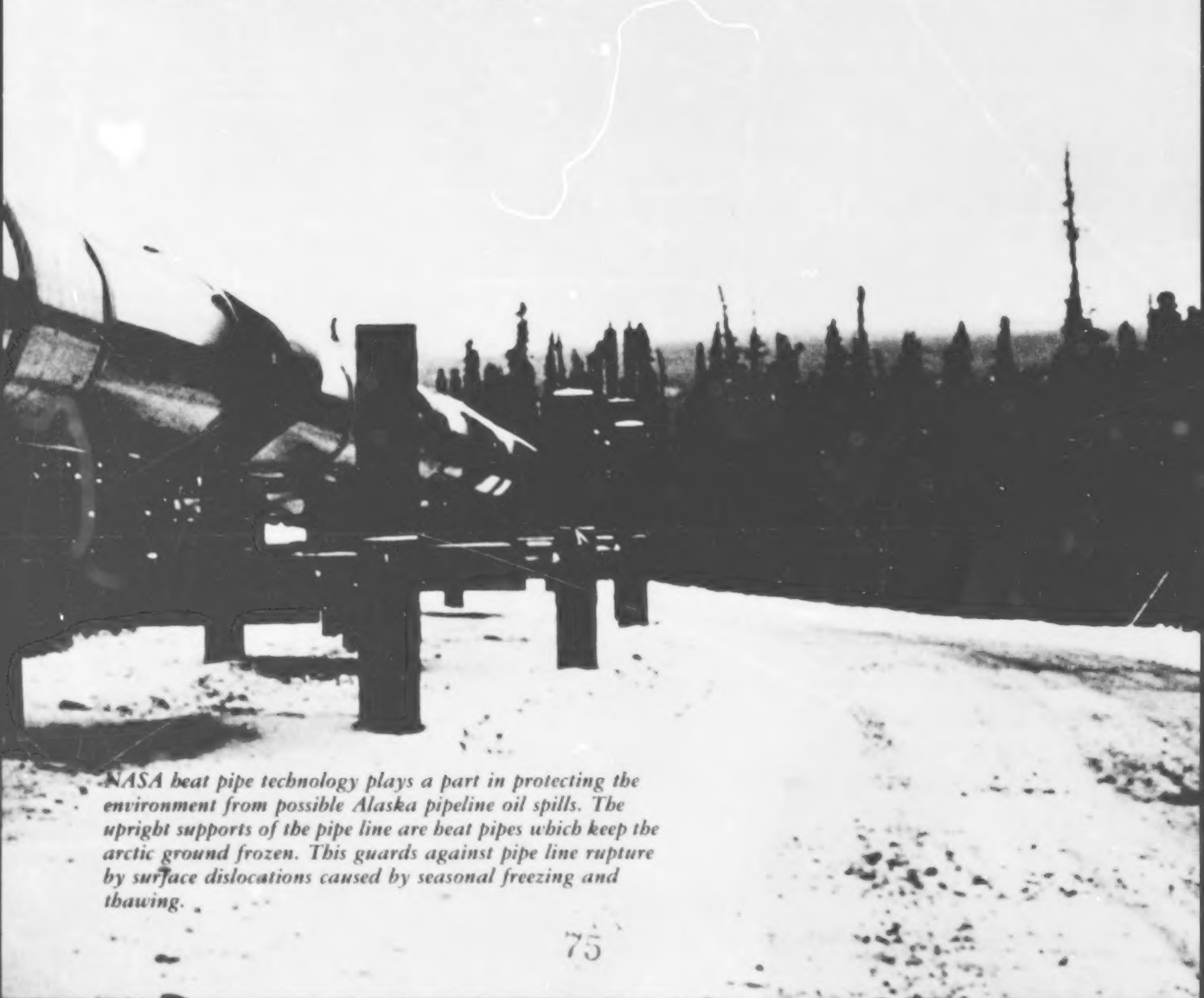
Heat Pipes for Alyeska

Alaskan oil flowing through the 800-mile pipeline to the ice-free port of Valdez on the Gulf of Alaska is partly an accomplishment of space technology.

Astounding as that claim may be, the fact is that the pipeline may never have been approved by Congress without the unique heat pipe, deliberately spun off from spacecraft where it was used routinely for cooling electronic equipment. In the Alaskan pipeline, heat pipes protect the tundra from possible pipe ruptures that could spill large amounts of oil over the land.

The heat pipe's job is to keep the arctic ground frozen. The permafrost soil alternately freezes and thaws with seasonal temperature changes, causing surface dislocations and problems for the builders. In winter, a phenomenon called frost-heaving uplifts the soil. It is something like the creation of highway potholes by the freezing of rainwater below the roadbed—but frost-heaving exerts far greater force. Conversely, thawing of the frost in summer causes the soil to settle unevenly. It is therefore necessary to keep the soil in a continually frozen state, negating the powerful forces which could weaken supporting structures and rupture the pipeline.

To do so, McDonnell Douglas Corp. applied heat pipe principles in the design of the vertical supports that hold up the four-foot diameter oil pipeline. Alyeska Pipeline Service Co., the consortium responsible for building and operating the trans-Alaska system, utilized some 76,000 McDonnell Douglas heat pipes varying in size—according to terrain requirements—from two to three inches in diameter and from 31 to 66 feet long.



NASA heat pipe technology plays a part in protecting the environment from possible Alaska pipeline oil spills. The upright supports of the pipe line are heat pipes which keep the arctic ground frozen. This guards against pipe line rupture by surface dislocations caused by seasonal freezing and thawing.

Firefighting aids, a faster method of tracing criminals, and a novel personal security device highlight technology transfers for better public safety.

dividends in safety

Few disasters are more devastating or more saddening than a raging forest fire. Even when no loss of life or property occurs, fire destroys an extremely valuable resource—the great trees of the American forests.

Over the years, while advances have been made in putting out fires—little has been done to predict them. "Knowing where a forest fire may occur and how it might act is almost as important as having the men and equipment to fight it," says William Innes, Jr., senior meteorologist for the California Division of Forestry (CDF).

Now such a capability exists that may fill a long standing need—an automatic system that sends fire prediction information from remote forest sites to central offices by satellite. Made up of sensors originally developed for space applications, and a combination of solar energy, wind energy, and commercial power, the ground element of the system is a tiny weather station that can be set up in hard-to-reach locations and left to operate automatically for a year or more without maintenance. The first working units were set up last year. By mid-1977 the CDF expects to have the initial complement of 25 working. Called automatic fire index stations, they were developed by NASA's Ames Research Center, in cooperation with the CDF, a division of California's Department of Conservation.

For years, CDF's fire prediction information came from daily fire-weather observations. Obviously, something more was needed. Innes explains: "More weather support is imperative. We need up-to-the-minute weather conditions to know when and where to send our attack forces to fires. Too many significant facts fall through the mesh when weather is sampled only once or twice a day."

Now, with the NASA system, the CDF gets fire weather data from the Geostationary Operational Environmental Satellite (GOES) every three hours at headquarters in Sacramento.

NASA-Ames built two prototypes and tested them within CDF forest areas before developing the final version—a relatively low cost system that weighs only 200 pounds, can be transported to the most remote forest areas by three people, and can be set up in one hour.

Each monitor has a weather sensor, a transmitter, and a power supply. The weather sensor obtains information on wind velocity and direction, solar radiation, relative humidity, and the moisture content of inflammable forest litter—pine needles, leaves, and grass, for example.

The transmitter can send sensor data to the satellite—operating at an altitude of more than 22,000 miles—using only 50 watts of power for short-burst transmissions. The transmitter is sealed in a waterproof can and buried within a two-inch-thick redwood container.

The station's power is provided by a rechargeable storage battery. In the operational test system, three different types of energy sources for recharging are being explored: solar panels, a windmill, and commercial gasoline powered generators.

Automated fire weather stations developed by NASA and now being used by the California Division of Forestry provide a means of predicting where a forest fire might occur. The stations employ aerospace sensors and a combination of solar energy, wind energy and commercial power. To avoid interference by trees and mountains, weather data is relayed by satellite from outlying stations to a central fire protection office.

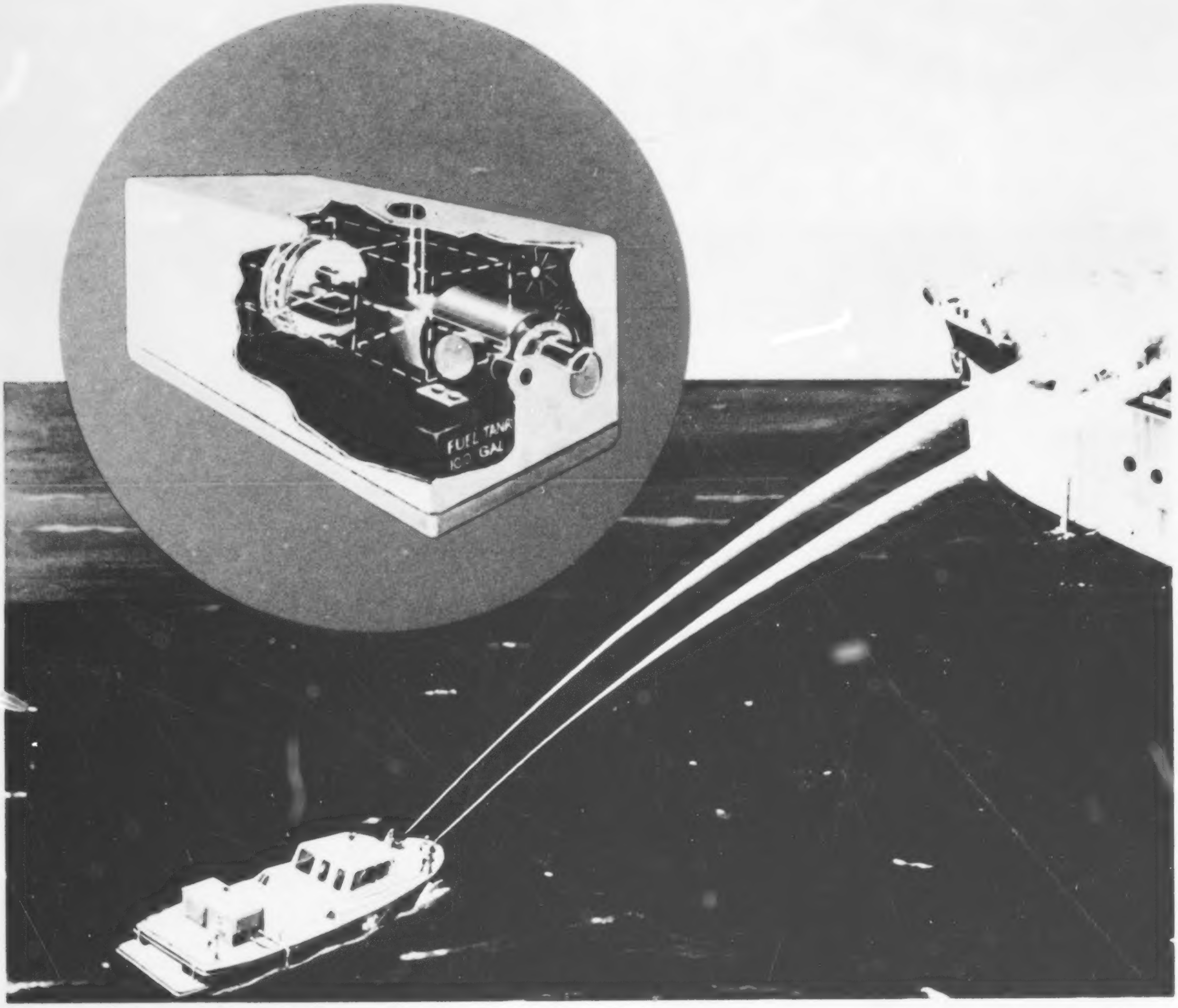
The flow of weather data follows an elaborate path from the forest to CDF's Fire Protection Office. Because mountains and trees block direct line-of-sight transmissions, the weather information is routed first to the GOES satellite. GOES then retransmits the signals to a computer complex in Suitland, Md. where reports from each transmitting station are identified by a code number. The CDF data are then relayed by land line to Sacramento, where another computer translates the information into a form usable for prediction. The entire process takes less than 90 minutes, sometimes less than an hour.

From evaluation of the initial network of 25 stations, covering only one region of the California forest, CDF will be able to determine the improvement in fire-suppression operations and how much it would cost to operate and maintain a broad system covering the whole state. If the system proves itself, CDF envisions a statewide network providing data for the most effective use of fire fighting resources.

Coast Guard Firefighting Module

In another anti-fire application, NASA is working with the U.S. Coast Guard to develop a portable firefighting module for combating shipboard or dock fires. Lightweight and completely self-contained, the module can be helicopter-transported to a ship's deck or to dockside. In a compact package, it has everything needed for fire fighting: its own pump,

Videofile is used by a number of law enforcement agencies in the U.S. and Canada. It is a computerized pictorial record-keeping system offering high reliability and rapid retrieval of information. Key components of Videofile are derived from a videotape storage and retrieval system developed for NASA.



NASA and the U.S. Coast Guard are jointly developing a lightweight, helicopter-transportable, completely self-contained firefighting module for combating shipboard and dockside fires. The project draws upon NASA technology in high-capacity rocket engine pumps, lightweight materials and compact packaging.

which delivers 2,000 gallons of sea water per minute, a quick starting gas turbine, hose, monitors, nozzles, protective suits, and other equipment.

NASA's Marshall Space Flight Center is directing the project, drawing on its experience in high-capacity rocket engine pumps, lightweight materials, and compact packaging acquired during the Skylab program. Northern Research & Engineering Corp., Cambridge, Mass., is building the module under NASA contract. A prototype is scheduled for acceptance and service testing this year.

Videofile for Law Enforcement

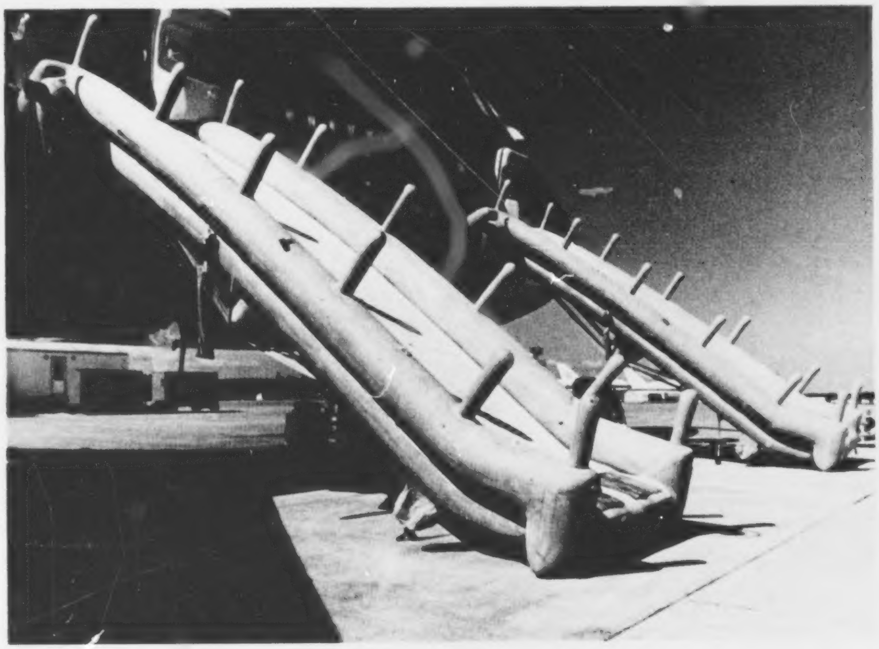
Components of a videotape storage and retrieval system originally developed for NASA have been adapted as a tool for law enforcement agencies.

Ampex Corp., Redwood City, Cal., built a unique system for NASA-Marshall. The first application of professional broadcast technology to computerized record-keeping, it incorporates new equipment for transporting tapes within the system. After completing the NASA system, Ampex continued development, primarily to improve image resolution.

The resulting advanced system, known as the Ampex Videofile, offers advantages over microfilm for filing, storing, retrieving, and distributing large volumes of information. The system's computer stores information in digital code rather than in pictorial form. While microfilm allows visual storage of whole documents, it requires a step before usage —developing the film. With Videofile, the actual document is recorded, complete with photos and graphic material, and a picture of the document is available instantly.

OWA
HIGHWAY
PATROL
.68 MFD
50 VDC

These Boeing 747 escape chutes, for rapid evacuation of passengers in a ground emergency, are inflated by filament-wound pressure vessels, 60 percent lighter than earlier inflation cylinders. Changeover to the new bottles, spinoffs from rocket motor casing technology, saves 200 pounds per airplane.



The Videofile is particularly valuable for law enforcement agencies because of its exceptional reliability and its compactness; it needs only a fraction of the space required by manual filing systems and it affords large savings in the record-keeping process. Videofile saves time as well as space. Fingerprints, photographs, and complete dossiers stored on videotape are immediately available for real-time viewing at any one of the agency's substations equipped with a TV-like console.

Videofile is being used by a growing number of law enforcement groups in the U.S. and Canada, but its utility is not limited to police work. American Republic Insurance Co. uses it for claims and rate analysis and it is in service with the Southern Pacific Railroad for filing half a million freight waybills monthly.

NASA technical information on flat conducting cable, widely used in spacecraft, contributed to the design of an improved communications system for police patrol vehicles.

Air Safety Spinoffs

Weight saving—even a matter of a few pounds—is an important consideration in airplane design and construction. Boeing saved 200 pounds simply by substituting a new type of compressed gas cylinder on their 747 commercial airliners.

For quickly evacuating passengers in the event of a ground emergency the 747 escape chutes allow passengers to slide to safety from the two-story height of the cabin deck. The chutes pop out of exitways and are automatically inflated in seconds by compressed air stored in pressure vessels.

Boeing's weight saving resulted from a recent changeover to a new type of pressure vessel built by Structural Composites Industries Inc. of Azusa, Cal. The company employs technology originally developed for rocket motor casings; the cylinders are constructed by winding fibers around an aluminum liner. This technique offers high strength for very low weight—in this case 60 percent less than the pressure vessels earlier used on the 747.

Another contribution to improved air safety is an underwater locator device. Called the "Pinger," it uses sonar techniques to locate aircraft crashed in water—or, more specifically, to recover the flight recorder aboard the airplane. Its recovery provides clues as to what caused the accident and suggests measures to prevent similar future occurrences. Until recently, there was no way to recover flight recorders aboard aircraft lost in water crashes.

The Pinger, now serving 95 percent of the airline industry, provides an answer. Key element of the Pinger system is a small, battery-powered transmitter, or homing beacon, included as part of the recorder package. For as long as 30 days, the transmitter sends out an acoustic signal from water depths up to 20,000 feet. The other element of the system is a receiver, used by search crews to home in on the transmitter's signal. Originating as a U.S. Navy project, this device was refined and further developed by NASA's Langley Research Center to retrieve submerged nose cones from research rockets. NASA's contractor for the transmitter portion of the system was Dukane Corp., St. Charles, Ill. who subsequently developed the commercial version.

Personal Alarm System

Trouble in the classroom is an unpleasant fact of modern life. Space technology can't stop the trouble from occurring, but it can prevent it from spreading.

In recognition of this, NASA and the Sacramento, Cal. Unified School District developed a personal security system based on space telemetry technology. The first application was for schools, but the simplicity and reliability of the system has made it more widely applicable.

The heart of the system is an ultrasonic pen-size transmitter. It can be used by prison guards, teachers, or others such as the handicapped and the elderly.

A police officer demonstrates how he would use the SCAN (Silent Communications Alarm Network) security system to summon aid in a cell block emergency. The pen-size SCAN device is an ultrasonic transmitter which sends a wireless alarm signal to the ceiling-mounted receiver, connected to a central display panel. At the central console, visual and audible alarms alert other police personnel and indicate location of the trouble.

When a problem arises, be it a threat of violence or a medical crisis, the pen transmits a silent signal to a nearby receiver. Within an institution, apartment or office building, the receiver may be one of many that are wired to a central console that will display the exact location of the emergency. With smaller systems, the receiver can sound an alarm, initiate an automatic telephone call, or activate any other type of equipment including doors, lights, machinery, etc. Sentry Products Inc., San Jose, refined the original system and now sells it under NASA license.

Skid-Resistance Research

Skidding causes many traffic accidents. Streets and highways with skid-resisting surfaces reduce the incidence of such accidents. In fact, resurfacing roads to improve skid resistance is now required by federal law. Skid resistance is measured by road testing with specially equipped skid trailers. A project underway at NASA-Langley may considerably reduce the cost of skid trailers, thus making them more widely available to highway departments.

For testing the skid resistance of aircraft runways, Langley engineers developed a relatively inexpensive test vehicle and a "pulsed braking" technique that is now being applied experimentally to road testing. The vehicle is a standard automobile modified to incorporate instrumentation, special test tires and valves, and a trailing fifth wheel for monitoring distance and velocity. The instrumentation includes a low-cost meter, a set of accelerometers that sense motion changes, and a chart recorder.

A NASA-developed five-wheeled vehicle serves as a mobile laboratory for testing roadway skid resistance. It does a job comparable to more expensive test vehicles, but at a fraction of the cost. Cost is a big factor to many communities, which need skid resistance data for improving road surfaces but can't afford highly expensive skid trailers and their elaborate instrumentation.

Last year the Langley vehicle was comparison-tested on seven different road surfaces at the Texas Transportation Institute. Results exceeded expectations. Accuracy of this new car in measuring highway skid resistance correlated almost exactly with that of a fully equipped test van provided by the Federal Highway Administration.

Emergency Lighting

A lighting system originally developed for NASA's Apollo and Skylab manned spacecraft resulted in a industrial spinoff and creation of a whole new company to produce and market the product line. The company is UDEC Corp., Waltham, Mass.

UDEC's "Multi-Mode" electronic lighting systems are designed for plant emergency and supplemental use, such as night lighting, "always-on" stairwell lights and illuminated exit signs. Their advantages stem from the qualities demanded for spacecraft installation: extremely high light output with very low energy drain, compactness, light weight, and high reliability.

The Multi-Mode system includes long-life fluorescent lamps operated by electronic circuitry, a sealed battery that needs no maintenance for 10 years, and a solid-state battery charger. A typical emergency installation consists of a master module with battery and an eight watt lamp, together with four remote "Satellight" modules powered by the master's battery. This installation can automatically supply illumination sufficient to read a newspaper in any part of a 20,000 square foot plant, insuring employee safety in the event of a main power blackout.

Stream Lite-20, produced primarily for use by law enforcement and other security agencies, is nine times more powerful than a home two-cell flashlight and five times as powerful as five-cell lights. It defines objects and people clearly at three and a half times the range of a conventional flashlight; users say it is like having a low beam auto headlight in your hand. Key elements of the SL-20 are a tungsten-halogen bulb and a spun aluminum reflector which combine to produce a brilliant white light close to natural sunlight, together with very sharp definition. Despite its power, the SL-20 is only a foot long and weighs one and three-quarter pounds; it is shorter and lighter than most five-cell flashlights used in security work. A bonus in savings and dependability is the fact that the SL-20's nickel-cadmium batteries are rechargeable; the flashlight fits in a holder/charger and automatically charges itself when not in use. Manufactured by Streamlight, Inc., King of Prussia, Pennsylvania, the SL-20 is an adaptation of a xenon arc lamp developed for the Apollo environmental test chamber at NASA's Johnson Space Center.

As a night lighting system for maintenance or security, UDEC fixtures can bypass the battery and operate on normal current at a fraction of the energy demand of conventional night lighting. Industrial customers have realized savings of better than ninety percent with UDEC night lights. UDEC started as a basement industry in 1972 but the company has already sold more than 1,000 lighting systems to building operators.

Exits of Boston's Exeter Street Theater are lighted by Multi-Mode electronic lights, commercial spinoffs from a lighting system developed for NASA's Apollo and Skylab manned spacecraft. Advantages of Multi-Mode lights stem from the qualities demanded for spacecraft use: high light output with low energy drain, compactness, light weight and high reliability.

The integral heating system, an entirely new concept of electronic food warming, provides a means of serving better looking, better tasting, more nutritious meals. It is now used by more than 40 hospitals and nursing homes, such as St. Mary Hospital, Hoboken, N.J.

This compact meal-heating unit developed for Apollo spacecraf crews served as the basis for a new method of preparing food. It can eliminate "tired food"—a problem common to many large medical institutions.

Innovative ideas offer better hospital food service, new equipment for food processing efficiency and improved nutrition for the elderly.

thought for food

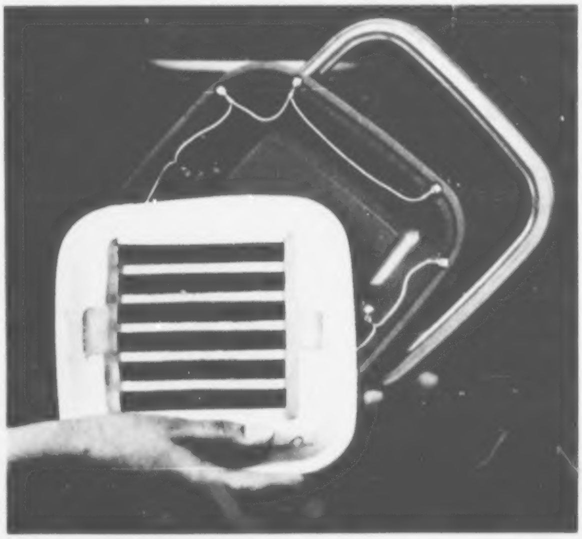
If you have ever been hospitalized, you are probably aware of a problem that has long troubled the staffs of most large medical institutions.

"Tired food," it is called. Food gets tired when there is too long a lapse between preparation and delivery to the patient. That happens often in hospitals which must serve a thousand or more meals daily, because food must be cooked well in advance, stored hot until mealtime, then moved to nursing units some distance from a central kitchen. In this lengthy process, the meal loses heat and moisture, looks unappetizing and, most important, its nutritional value is diminished.

Food no longer need suffer fatigue, thanks to a space spinoff called the integral heating system. Developed and produced by 3M Co., St. Paul, Minn., the system features an entirely new concept of electronic food warming—no gas flame, no electric rods, no thermostats, no radiation. Now in use at more than 40 U.S. hospitals and nursing homes, it provides a means of serving piping-hot meals with better color and taste retention, no burning or drying out, and no loss of nutrition. Integral heating appears slated for wider acceptance because in solving a nagging problem it also pays dividends in reduced labor costs, less waste, and electricity savings of as much as 60 percent.

Integrated heating traces its lineage to a similar but less sophisticated 3M design intended for airline use, which was redeveloped as a food-service unit for manned spacecraft. The basic commercial design was refined and improved to NASA specifications, including addition of miniaturized control circuitry and energy-conservation features to meet the reliability and energy-efficiency requirements of manned spacecraft.

Components of the integral heating system include a unique dish that serves as both plate and oven, and a roll-around control module that provides the heat source. Metal buttons on the shell of the dish-oven make electrical contact when they slide into the control module on conductor rails. A resistive coating on the bottom of the dish-oven converts electrical energy to heat. The device uses less electricity because the heat goes directly to the food; it is not wasted by heating oven walls and surrounding air. Efficiency of the integral heating



Key to the integral heating system's efficiency is the "dish-oven," which doubles as a heating unit and serving plate. The dish-oven consists of a sealing frame (top) a plastic outer shell (center) and the ceramic inner dish. A special coating on the bottom of the inner dish (dark areas) transforms electrical impulses into heat.

An Armour technican checks meat to see how tender it will be after cooking. Called the Tenderometer, the testing device is a spinoff from a gage originally developed for the Surveyor lunar lander.

system is ninety percent or more—as compared to a range of thirty to fifty percent in conventional equipment.

Tenderness Tester

Space telemetry has been transferred to food processing in the Armour Tenderometer, an instrument that predicts the tenderness of meat. The space component of the instrument is a sensitive, highly reliable strain gage originally produced for NASA's Surveyor lunar lander and other space programs by BLH Electronics, Waltham, Mass.

Several years ago Armour & Co. began to develop a method of testing a hanging carcass to predict how tender the meat would be after cooking; no such method then existed.

After considerable experimentation, Armour came up with a manifold-mounted group of needle-like probes, which when stuck into a carcass, could measure the degree to which the meat resisted penetration. This provided a basis for predicting tenderness, but the development required one more step: a device that could translate meat resistance into an electrical readout. Armour found it in the BLH strain gage.

The resulting Tenderometer, now a standard and important part of Armour's meat processing operation, includes a large, 10-pronged fork which is plunged into a carcass and a cable-connected, hand-held electronic device that translates the sensings of the prongs into a tenderness reading on a dial. The instrument is used by Armour to select and guarantee a premium line of beef known as TesTender, whose annual sales run into tens of millions of pounds.

Space Technology for Tuna Boats

The Saturn V booster burns ultra-cold liquefied hydrogen fuel, which must be protected from the intense heat of the launch vehicle's mighty rocket engines. This necessitated development of superefficient insulation to keep the fuel tanks cold. One of two methods used was a spray-on polyurethane foam technique devised by Rockwell International Corp. The technique now has found commercial application as insulation for tuna boats.

Freshly-caught tuna is stored below decks in wells cooled to about zero degrees by brine circulated through a refrigerating system. The wells formerly were insulated by cork or fiberglass, but both

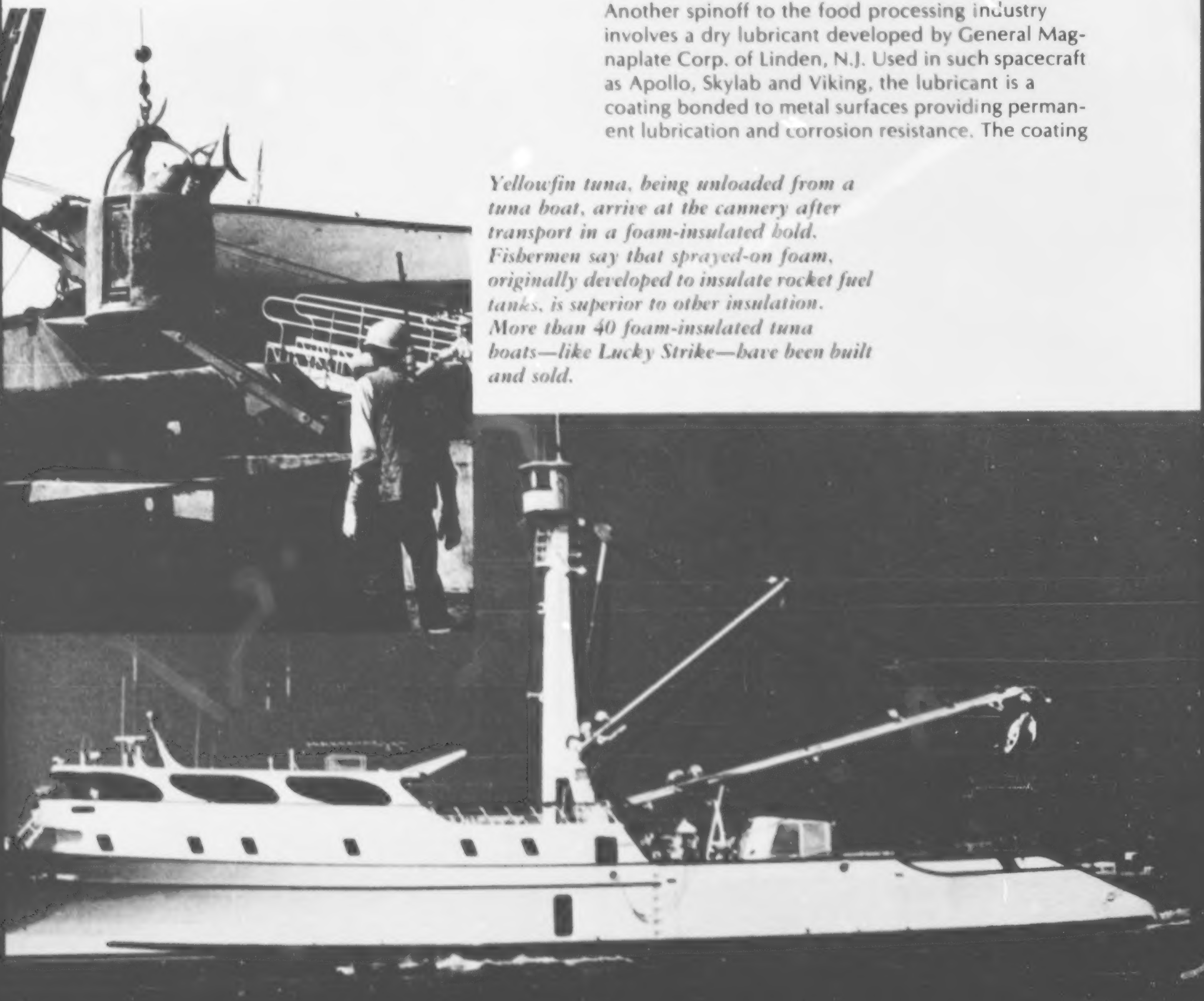
materials were subject to deterioration; cork, for instance, needs replacement every three years.

The Campbell Machine Division of Campbell Industries, San Diego, which manufactures and repairs large boats for the commercial fishing industry, was looking for a better way to insulate tuna storage wells. Learning of the Rockwell technique, Campbell contracted for a test installation on one boat, then bought its own equipment and adopted the spray-foam procedure for their boats.

The foam hardens after application. It not only is a superior insulator, it also is considerably lighter and easier to apply. Fishing industry spokesmen say that foam insulation is far more reliable, efficient and economical than prior techniques. More than 40 foam-insulated tuna boats, ranging in cost from $1 million to $4 million, have been built and sold. Principal customers are Ralston Purina's Van Camp Seafood Division and Star-Kist Inc.

Bonded Lubricants

Another spinoff to the food processing industry involves a dry lubricant developed by General Magnaplate Corp. of Linden, N.J. Used in such spacecraft as Apollo, Skylab and Viking, the lubricant is a coating bonded to metal surfaces providing permanent lubrication and corrosion resistance. The coating



Yellowfin tuna, being unloaded from a tuna boat, arrive at the cannery after transport in a foam-insulated hold. Fishermen say that sprayed-on foam, originally developed to insulate rocket fuel tanks, is superior to other insulation. More than 40 foam-insulated tuna boats—like Lucky Strike—have been built and sold.

Bonded lubricants developed for the lunar drill and other space applications help to increase production efficiency in food processing plants. Application of one type of space-developed dry lubricant solved a breakdown problem with this meat packaging machine and broke a production bottleneck. In another application, the bonded lubricant improved sanitation and extended the service life of this rotary ice cream packaging machine.

lengthens equipment life and permits machinery to be operated at greater speed, thus increasing productivity and reducing costs.

Bonded lubricants are used in scores of commercial applications. They have proved particularly valuable to food processing firms because, while increasing production efficiency, they also help meet the stringent USDA sanitation codes for food-handling equipment. For example, a cookie manufacturer plagued by production interruptions because sticky batter was clogging the cookie molds had the brass molds coated to solve the problem. Similarly, a pasta producer faced USDA action on a sanitation code violation because dough was clinging to an automatic ravioli-forming machine; use of the anti-stick coating on the steel forming plates solved the dual problem of sanitation deficiency and production line downtime.

Meals for the Elderly

NASA is drawing upon its food-preparation expertise to assist in solving a problem affecting a large segment of the American population.

In preparation for manned space flight programs, NASA became experienced in providing astronauts simple, easily-prepared, nutritious meals. That experience now is being transferred to the public sector in a cooperative project managed by Johnson Space Center. Called Meal System for the Elderly, the project seeks to fill a gap by supplying nutritionally balanced meal packages to those who are unable to participate in existing meal programs.

Many such programs are conducted by federal, state and private organizations, including congregate hot meal services and home-delivered "meals on wheels." But more than 3.5 million elderly Americans

A volunteer is delivering a "Seven Pack" which provides an elderly recipient one easily-prepared hot meal daily for a week. The Seven Pack is lightweight and designed for mailing as well as personal delivery, and can be stored without refridgeration for as long as two years.

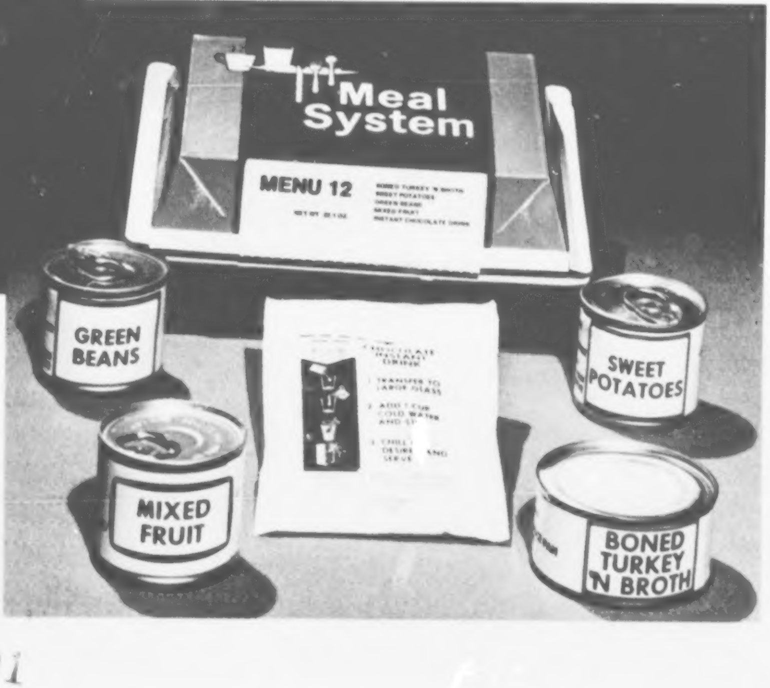
are unable to take advantage of these benefits. In some cases, they live in rural areas away from available services; in others, they are handicapped, temporarily ill, or homebound for other reasons.

Looking for better nutrition for elderly, the Texas Governor's Committee on Aging contacted Johnson Space Center. Would it be possible, the committee asked, to apply NASA's space food knowledge to solve the problem?

NASA officials considered the idea feasible and, early in 1975, Johnson Space Center initiated a pilot program in cooperation with other organizations. The University of Texas LBJ School of Public Affairs contributed its expertise in social services. United Action for the Elderly Inc., a meal service organization in Austin, took charge of field demonstrations. The Texas Research Institute of Mental Sciences conducted user surveys and taste tests. NASA accepted responsibility for overall program management and for the design, development and production of the meals. The NASA-Martin Marietta Biomedical Application Team provided project engineering support. NASA also employed the contract services of Martin Marietta Corp. and Technology Inc.

Meal System

Meal System for the Elderly, a cooperative program in which the food-preparation expertise NASA acquired in manned space projects is being utilized to improve the nutritional status of elderly people. The program seeks to fill a gap by supplying nutritionally-balanced food packages to the elderly who are unable to participate in existing meal service programs.



Here is one of 21 menus available in the Meal System for the Elderly program. Last year, a field test involving delivery of some 10,000 meals brought enthusiastic response from elderly participants and volunteer field workers.

NASA research is supporting the electric car revival and making bridges safer, among other advances in transportation.

new technology for transportation

The electric car is staging a comeback. It is clean and quiet, offering a potential environmental boon. It burns no gasoline, a major advantage to the individual and to the national aim of reducing petroleum imports.

In the United States and several other nations, researchers are taking a new look at the electrocar. They are predicting that current drawbacks can be remedied and that an efficient battery-powered auto can be available within a decade. And space technology is playing a part in reviving a once-promising vehicle.

If you're under 60, chances are you don't remember the electric auto. Invented in 1887, it provided strong competition for the gasoline-powered car in the first decade of this century. The "petrocar", as some called the gasoline-driven vehicle, was a noisy, rattly, smelly smoke-belcher. The noiseless electric car didn't frighten horses and it was advertised as safer. Its battery needed recharging every 20 miles or so, but that was not too great a disadvantage since nearly all auto travel was local.

After 1910, however, internal-combustion technology advanced rapidly while electric-auto technology stagnated. The electrocar still held the noise advantage, but its lack of range caused its downfall as a network of roads and highways burgeoned and auto touring became the rage. Electric vehicles then faded gradually from view.

The key to the electrocar's possible comeback as a passenger vehicle is the battery, although advances are also required in design, controls, and drive trains. Studies show that a car capable of averaging 82 miles

This Postal Service van is a test vehicle for a NASA-developed nickel-zinc battery that may spark the electric automobile's comeback. Based on space satellite battery technology, the nickel-zinc battery promises longer life and twice the range of existing commercially-available batteries.

a day on a single battery charge would meet 95 percent of the need for a full-service urban vehicle in the United States. Present commercially available batteries, which have lead electrode plates in an acid solution, can't meet the range requirement.

NASA's Lewis Research Center undertook research toward a practical, economical battery with higher energy density. Borrowing from space satellite battery technology, Lewis came up with a nickel-zinc battery that promises longer life and twice the range of the lead-acid counterpart. Lewis researchers fabricated a prototype battery and installed it in an Otis P-500 electric utility van, using only the battery space already available and allowing battery weight equal to that of the van's conventional lead-acid battery.

In initial tests, the nickel-zinc battery delivered 190 stop-and-go driving cycles per charge, compared with 99 for the lead-acid battery. At a constant speed of 20 miles per hour—a test speed, not the ultimate expected—the nickel-zinc battery gave the van 55 miles on a single charge while the lead-acid battery yielded less than 30 miles.

X31002
Otis

Lewis is continuing research aimed at improving the nickel-zinc battery's performance, life and competitive cost. In a joint NASA-U.S. Postal Service field test program, nickel-zinc batteries will be installed in mail pickup and delivery vans. The Postal Service already has some 450 electric vans, and plans a large-scale expansion utilizing longer-range batteries.

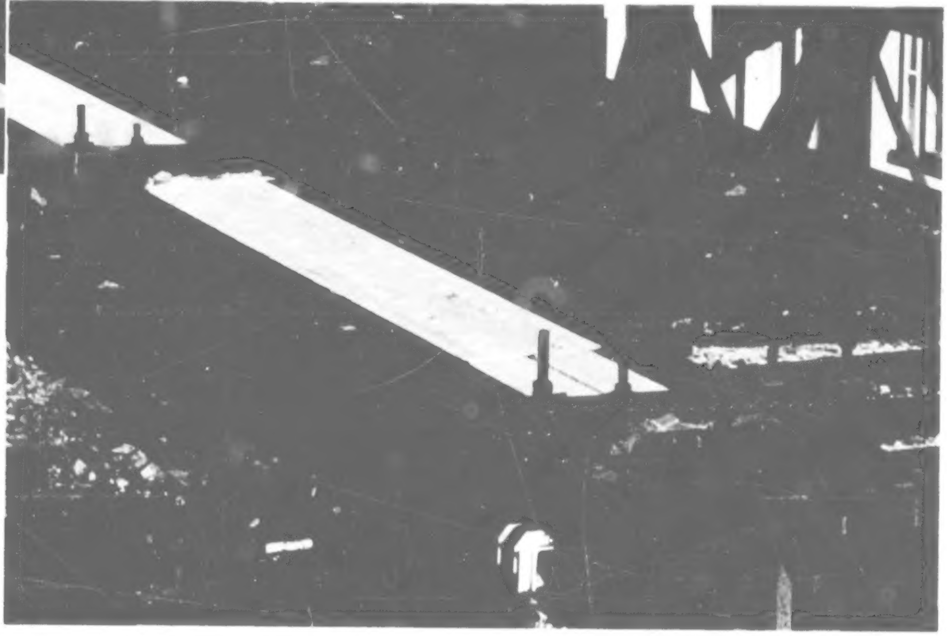
NASA will further evaluate the new battery's potential for urban family use in a test vehicle. Lewis researchers feel that a nickel-zinc battery, producible within five years, could drive a car 120 miles at an average speed of 40 miles per hour on a single charge—exceeding the predicted requirement for a viable urban vehicle.

These toll booths, at the Evergreen Point Bridge near Seattle, Washington, have air purifiers whose design profited from NASA "clean room" airflow technology. The booth's airflow system retards infiltration of contaminated air and decreases the toll collector's inhalation of engine exhaust fumes.

Toll-Booth Purification

For many years, toll collectors on turnpikes and bridges have been subjected to a health hazard from engine-exhaust. Fumes are particularly strong at toll booths because drivers decelerate from high speeds then quickly accelerate after paying the toll. To counter the exhaust hazard, Washington state decided to equip its toll booths with air purifiers, but available purification systems were found unacceptable; they created severe drafts because uniform air flows could not be attained.

NASA's Technology Application Team at Stanford Research Institute searched available information and suggested a transfer of clean-room technology



A section of Philadelphia's Elevated System is serving as an East Coast facility for testing a NASA-developed anti-corrosion coating which offers improvements over commercially available coatings. Salt spray makes corrosion a particular problem for coastal area structures and NASA's zinc-rich coating offers economies in easier application and longer life. The coating is also undergoing evaluation in the Northeast as a method of protecting road vehicles against corroding salts used as anti-icing measures.

employing the use of the same laminar flow techniques found in environmental control systems of clean rooms used for contamination-free assembly of precision aerospace equipment. That information, from technology originally developed by NASA and the Energy Research & Development Administration was incorporated in the design of a prototype toll booth purifier.

The draft-free design includes a "diffusor", which blows clean air out the toll booth doorway, thus retarding the infiltration of contaminated air. The net effect is a decrease in the toll collector's inhalation of exhaust fumes. The Washington Department of Highways installed the prototype system in a toll booth at the Evergreen Point Bridge near Seattle. After a successful two-year test, the department now has equipped all 10 of the bridge's toll booths with the air purifiers.

Anti-Corrosion Coating

A spinoff with economic potential, because of very wide applicability, is a NASA-developed anti-corrosion coating. Because of exposure to salt spray, coastal or ocean structures—bridges, ships, oil rigs, and pipelines, for example—require more corrosion protection than is needed inland. One study showed that a coating with a 25-year lifetime inland was good for only four to six years in coastal areas.

Most anti-corrosion coatings are formulated of zinc or aluminum dust in an organic binder. Existing zinc-rich formulations require two coats. A longer-lasting, single coating is needed to counter rising maintenance costs.

NASA-Goddard developed a zinc-rich coating with a special binder that exhibits longer life and superior adhesion characteristics—so that only a single coat is required. Unlike conventional coatings, the NASA compound is easy to mix and it requires no straining before application; its materials also cost less. Thus the new coating offers cost advantages in materials, labor hours per application, and fewer applications over a given time span.

The NASA coating is now undergoing test on a number of coastal area structures. In a cooperative effort with the Philadelphia Mayor's Science and Technology Council, the coating has been applied to sample sections of the Frankford Elevated System's steel support structure. On the West Coast, it is being tested on facilities of the Pillar Point Satellite Tracking Station, Pillar Point, Cal. and on segments of the Golden Gate Bridge. It is also undergoing evaluation as an undercoating to protect road equipment against de-icing salts; the coating was applied to the underside of a truck and its performance is being recorded periodically by the Vermont Department of Highways. NASA has issued patent licenses to two paint companies and the coating is expected to be commercially available this year.

Safer Bridges

Bridges are safer today, thanks to work by U.S. Steel Corp.'s Research Laboratory in Monroeville, Pa., in which NASA technology played a supporting role.

Bridge materials and other metal structures may develop flaws during their service lifetimes. Such flaws can affect the structural integrity of the part. Thus, it is important to know the "fracture toughness" of a structural part, or its ability to resist cracks.

NASA has long experience in developing fracture toughness tests for aerospace hardware. Since 1960, NASA-Lewis has worked closely with the American Society for Testing & Materials. Lewis and NASA-funded industrial contractors have made many important contributions to test procedures, now recommended by ASTM, for measuring fracture toughness.

U.S. Steel's Research Laboratory used a NASA-Lewis fracture toughness procedure in developing a low-cost method for testing structural steels. An important area of the steel company's work was development of fracture toughness requirements for bridges. These requirements were adopted by the Federal Highway Administration and the American Association of State Highway & Transportation Officials; they are now mandatory for all federal-aid highway programs in the United States.

Safer bridges are among a number of spinoff benefits from NASA procedures for testing "fracture toughness" of a structural part, meaning its ability to resist cracks that might cause failure. The New River Bridge in West Virginia, shown under construction, is the world's largest single span bridge. U.S. Steel fracture toughness requirements for such bridges include NASA-developed test procedures.

NASA's contribution to fracture toughness testing represents a broad area of spinoff. NASA-Lewis procedures have been used in testing a variety of structures and systems, ranging from nuclear reactors and power generating equipment to tractors and plows. In addition to bridge safety, another transportation-related example involves production of snowmobiles. Deere & Co., Moline, Ill., used the NASA technology as a basis for selecting better aluminum alloys and improving quality control procedures to reduce the chance of failure in high-speed rotary components of snowmobiles.

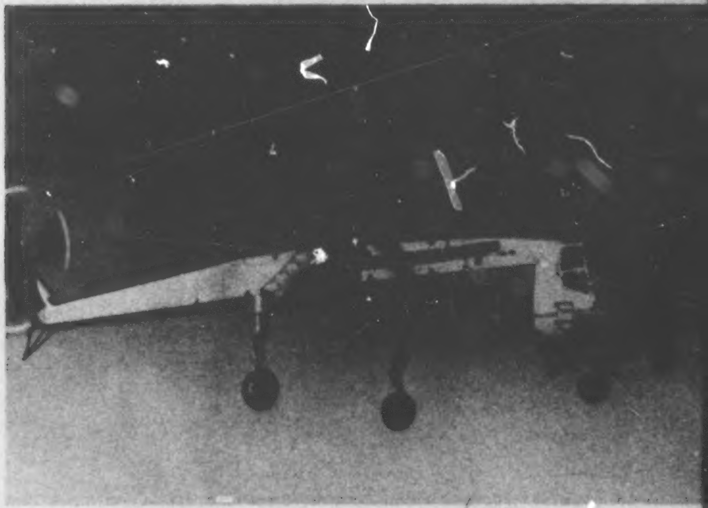
Log Truck-Weighing System

ELDEC Corp., Lynwood, Wash., built a weight-recording system for logging trucks based on electronic technology the company acquired as a subcontractor on space programs such as Apollo and the Saturn launch vehicle. ELDEC employed its space-derived expertise to develop a computerized weight-and-balance system for Lockheed's TriStar jetliner.

This snowmobile benefited from NASA fracture toughness procedures. The manufacturer—Deere and Company—used the NASA technology to select better metals and reduce chances of failure in high-speed rotary components.

TRUCK
ELDEC
TRAILER
ROADLAMP
OFF
LOW

NASA aircraft-icing research data resulted in design modifications to the Sikorsky S-64 Skycrane, expanding the helicopter's utility.



NASA-sponsored technology, acquired in the Apollo program, was adapted by a contractor to measure the weight of logging trucks. An instrument in the truck cab displays electronically-computed weight data, enabling truck operators to improve earnings by maximizing loads without exceeding legal highway weight limits.

ELDEC then adapted the airliner system to a similar product for logging trucks. Electronic equipment computes tractor weight, trailer weight and overall gross weight, and this information is presented to the driver by an instrument in the cab. The system costs $2,000 but it pays for itself in a single year. It allows operators to use a truck's hauling capacity more efficiently since the load can be maximized without exceeding legal weight limits for highway travel. Approximately 2,000 logging trucks now use the system.

Iceproofing Helicopters

NASA aircraft-icing research has been applied to expand the utility of the big flying-crane helicopter built by the Sikorsky Aircraft Division of United Technologies in Stratford, Conn. Sikorsky wanted to adapt the Skycrane, used in both military and commercial service, to lift heavy external loads in areas where icing conditions occur; ice build-up around the engine air inlets caused the major problem.

NASA-Lewis has a special wind tunnel for injecting super cooled water droplets into the wind thereby simulating a natural icing cloud and observing how ice builds up on various shaped surfaces. From Lewis, Sikorsky engineers obtained information which optimized the design of the inlet anti-ice system. The resulting design proved to be an effective anti-icing modification for the flying crane. Sikorsky is also using additional Lewis Icing Research Tunnel data in its development of a new VTOL (Vertical Take-Off and Landing) aircraft.

Space technology helped conque
the world's tallest mountain an
it contributes to a variety of new product
for sports and recreation

sports and recreation

Last October 8, American climbers Chris Chandler and Bob Cormack battled freezing cold and hundred-mile-an-hour winds to reach the 29,028-foot summit of Mt. Everest in the Nepalese Himalayas.

Chandler and Cormack were members of the American Bicentennial Everest Expedition, which included 12 climbers and some 500 porters. Only Chandler and Cormack made it to the top; a frozen oxygen regulator forced their Sherpa guide, Ang Phurba, to turn back in the last thousand feet.

The climbers' skill and courage were the main ingredients of the triumph, but NASA technology played an important supporting role. The transfer from space was the oxygen bottle, originally developed as rocket propellant tanks at NASA-Lewis. The bottles are produced by Luxfer USA Ltd., Riverside, Cal. and Compositek Engineering Corp., Buena Park, Cal.

In order to sustain human life at elevations above 23,000 feet, climbers must breathe oxygen full time—even while sleeping. Among the 40,000 pounds of supplies hauled 140 miles from Katmandu, Nepal to Mt. Everest were 200 oxygen bottles of special design. The individual bottle is an aluminum cylinder overwrapped with reinforcing fiberglass filaments; each bottle is wrapped with 1670 miles of filament three times finer than human hair. This type of construction reduces weight while providing a stronger cylinder. The extra strength permits higher air pressures, or more oxygen in the same volume. Compared with steel cylinders used on previous expeditions, the Luxfer-Compositek bottles—which, incidentally, were filled by NASA's Johnson Space Center—contain approximately twice as much oxygen although they weigh almost 20 percent less.

The weight and air volume advantages of the new bottles reduced the number of cylinders needed and reduced the overall breathing-system weight requirement by about half. This enabled the porters to carry more of other vital equipment needed at the high altitude camps.

The space technology bottles were particularly important in the assault on the summit, which started at an elevation of 27,450 feet. At this level, climbers can carry only 35 pounds. On previous expeditions, the weight of two cylinders—an active and a spare—made up the bulk of the weight allowance. The new bottles saved Chandler and Cormack five and a half pounds each. Additionally, the greater air volume of the new bottle allowed them to drop off the spare at the base of the summit for pickup on the return, lightening the load for the final climb. Thus, space technology made a significant contribution to the success of the American Bicentennial Everest Expedition.

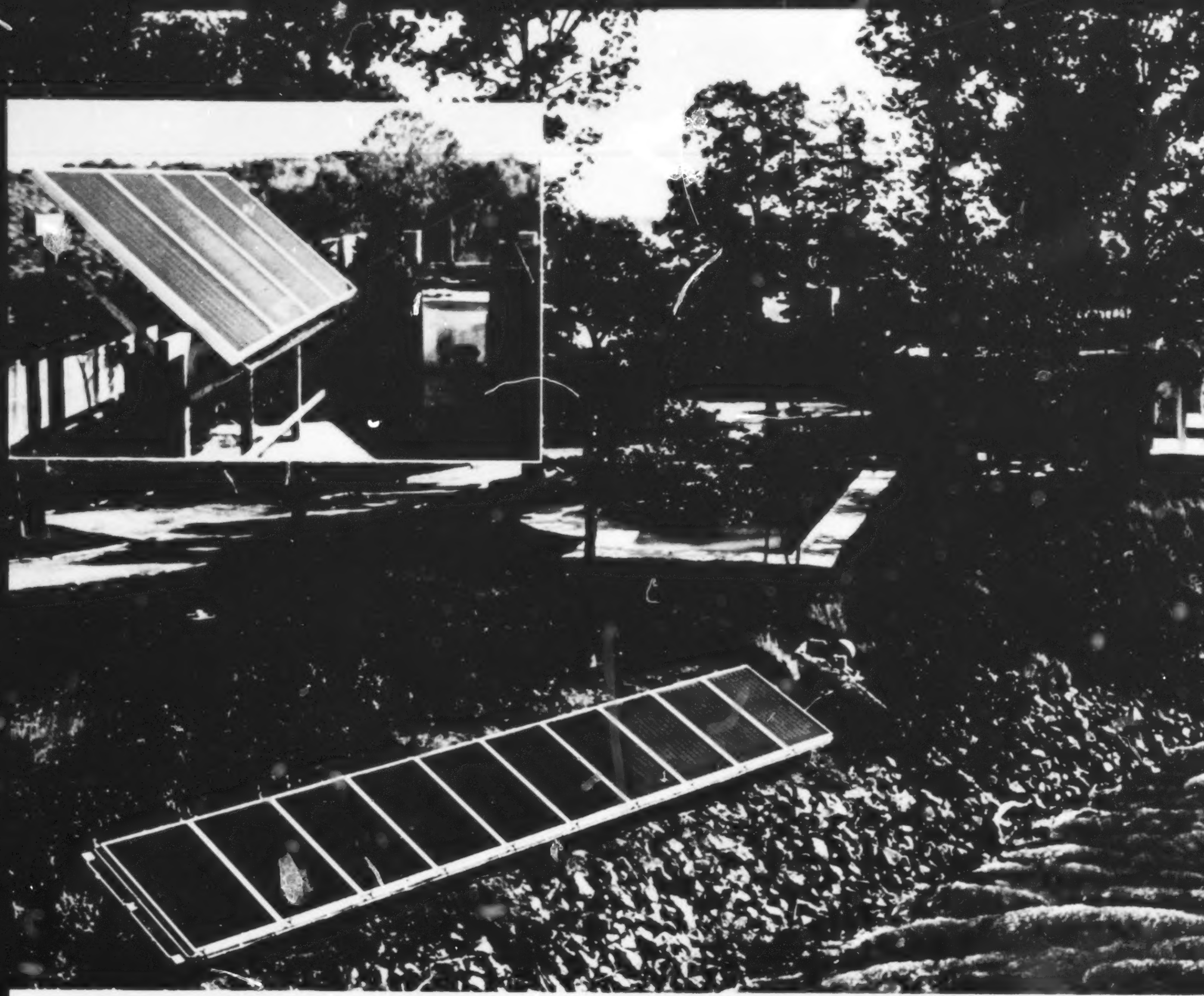
The Everest application is one example of many technology transfers to sports and recreation. A representative sampling follows.

A lightweight, higher-capacity oxygen bottle—derived from rocket propellant tank technology—proved an important aid in the 1976 ascent to the summit of Mt. Everest by members of the American Bicentennial Everest Expedition.

ong a number of solar energy tests being jointly conducted by
SA's Lewis Research Center and the Energy Research and
elopment Administration are a sun-powered refrigerator and a
-pack mounted power supply for radios. Both use solar cells,
ecraft power sources which convert sun energy into electricity.
refrigerator, which has potential utility for outdoor campers, is
peration at a trail construction camp in Isle Royale National
k, a remote wilderness in Michigan's Lake Superior where
ricity is available only at park headquarters. Trail maintenance
s working in the back country get food supplies only once
kly; with refrigeration they can enjoy a more varied and
ritious diet. Solar cells provide power to run the refrigerator and
harge its batteries for an alternate power supply when sun is not
ilable.

t the request of Inyo National Forest personnel NASA-Lewis also
eloped a back-pack system. The lightweight solar cell pack (on the
k strap in photo) charges batteries for portable two-way radios
l by trail guards, who are on patrol for as much as two weeks at a
e. Guards want continuous communication with the District
tion, but battery capacity precludes such operation. With the solar
power supply, guards can use their radios 24 hours a day.

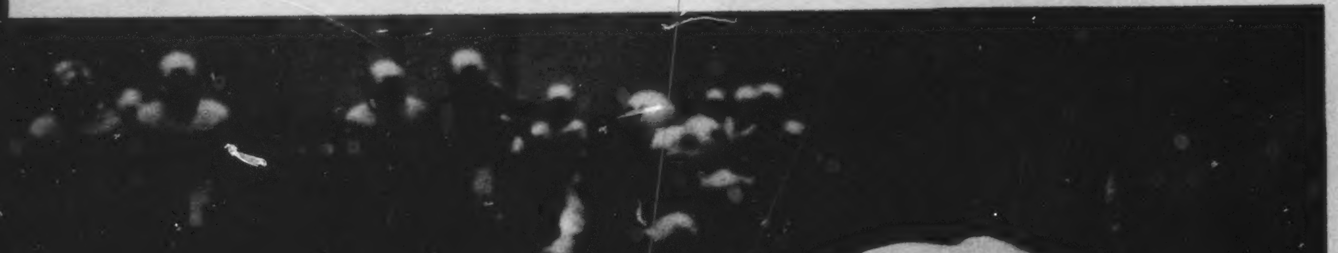
The space-spinoff filament-wound air bottle has other applications, among them breathing equipment for scuba divers.



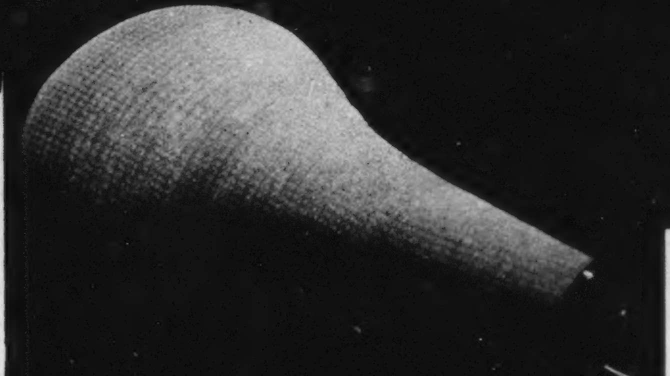
This swimming pool on the James River near Williamsburg, Virginia, is solar heated by the array of 10 flat plate collectors in the foreground. A smaller suburban pool in Florida requires four collectors. The solar array is built by Solarmatic Division, OEM Products Inc., Brandon, Florida. Solarmatic was formed to produce the collectors after OEM spent $100 on a NASA search of solar energy literature. The NASA Industrial Applications Center at the Research Triangle Park, N.C., provided OEM the technical information sufficient to enable that company to launch the Solarmatic venture.

Helmets used by these Little Leaguers offer a new level of protection for football players because they have three times the shock-absorbing capacity of earlier types. The key to shock reduction is an interior padding of Temper Foam, an elastomeric, open-celled material first used by NASA's Ames Research Center in the design of aircraft passenger seats. Little League players and professionals such as the Dallas Cowboys wear the helmets that are manufactured by Protective Products, Grand Prairie, Texas.

Temper Foam has a number of applications in sports because of its shock absorbing capacity and other special properties such as variable density. Here a trainer applies lightweight form-fitting Temper Foam to a high school football player for body protection. The energy-absorbing material is also used in baseball chest protectors and as added protection in soccer shin guards.



NASA technology in protective clothing for astronauts is finding new application in a line of outdoor gear produced by Comfort Products, Inc., Aspen, Colorado. The company supplies leading ski boot manufacturers with built-in rechargeable electric footwarmers, the design of which was borrowed from Apollo heating element circuitry. ThermaFlex, a woven mesh material designed to allow air to flow under and around an astronaut's feet, has a number of applications. Among them are the Procover "stay-dry" bicycle seat and the Profoot Insole, for more comfortable athletic and outdoor footwear.



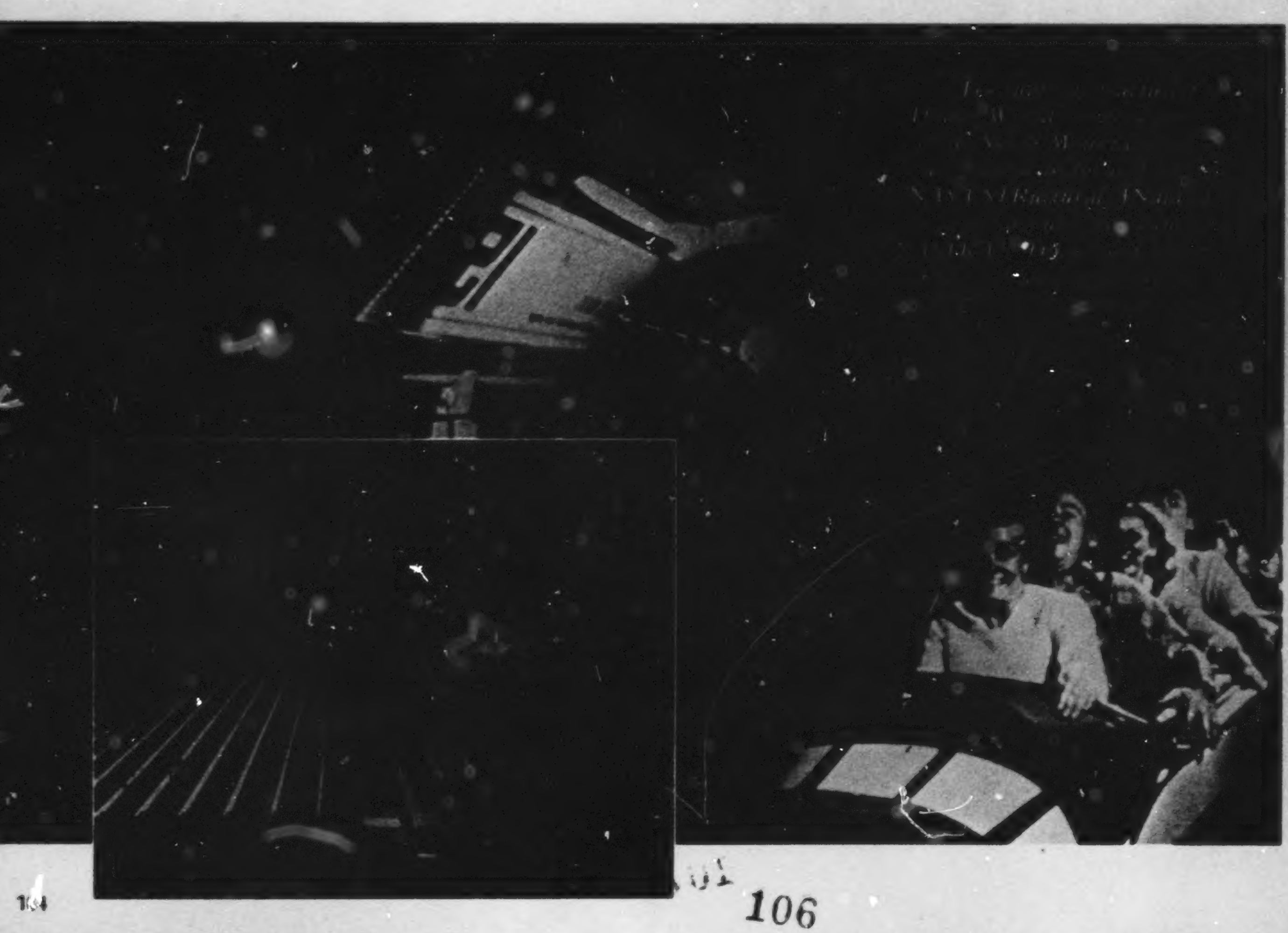
A versatile computer program for better design of structures heads a list of aerospace spinoffs improving industrial productivity.

industrial productivity

A roller coaster isn't ordinarily associated with space technology. Except, of course, "Space Mountain," the exciting coaster ride at Disney World.

The roller coaster was designed by WED Enterprises, the research division of Walt Disney Productions, Glendale, Cal. The task was to design a support structure for the tracks which would be totally safe and yet not overstrong. Overstrengthening adds nothing to safety; it simply wastes money in unneeded steel. WED engineers heard of a NASA-developed computer program which simplifies the job of analyzing structures and used it to gain substantial savings in labor and materials. Success in the initial effort led to re-use of the computer program in designing a similiar ride at Disneyland, to be available this year.

The roller coaster example is one of hundreds of cases where industry has benefited from NASTRAN, an acronym for NASA Structural Analysis Program. Since 1970, the computer program has been available from NASA's Computer Software Management & Information Center (COSMIC) at the University of Georgia. Cost averages $3,000 to $4,000, usually a mere token compared to the savings. In some cases, the NASTRAN investment has returned several millions



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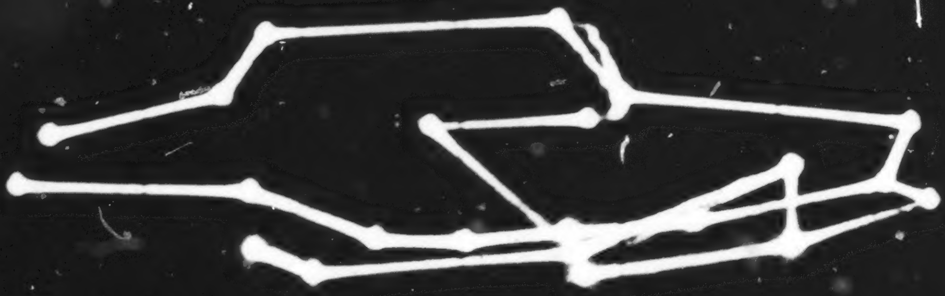
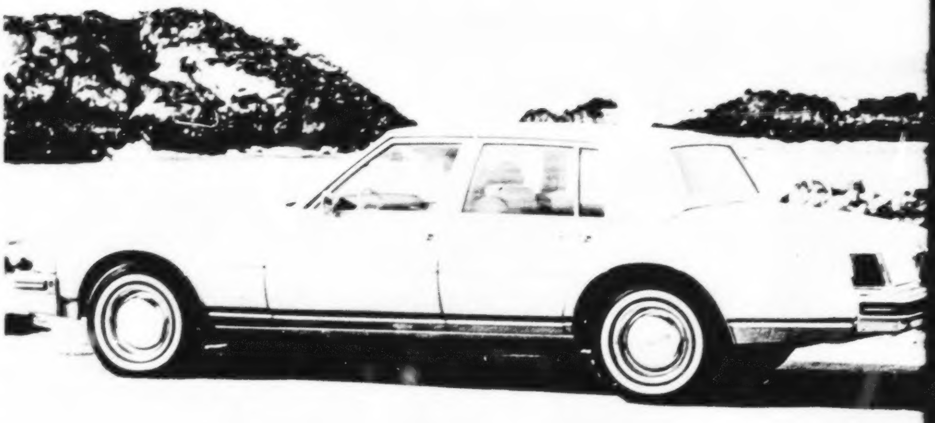
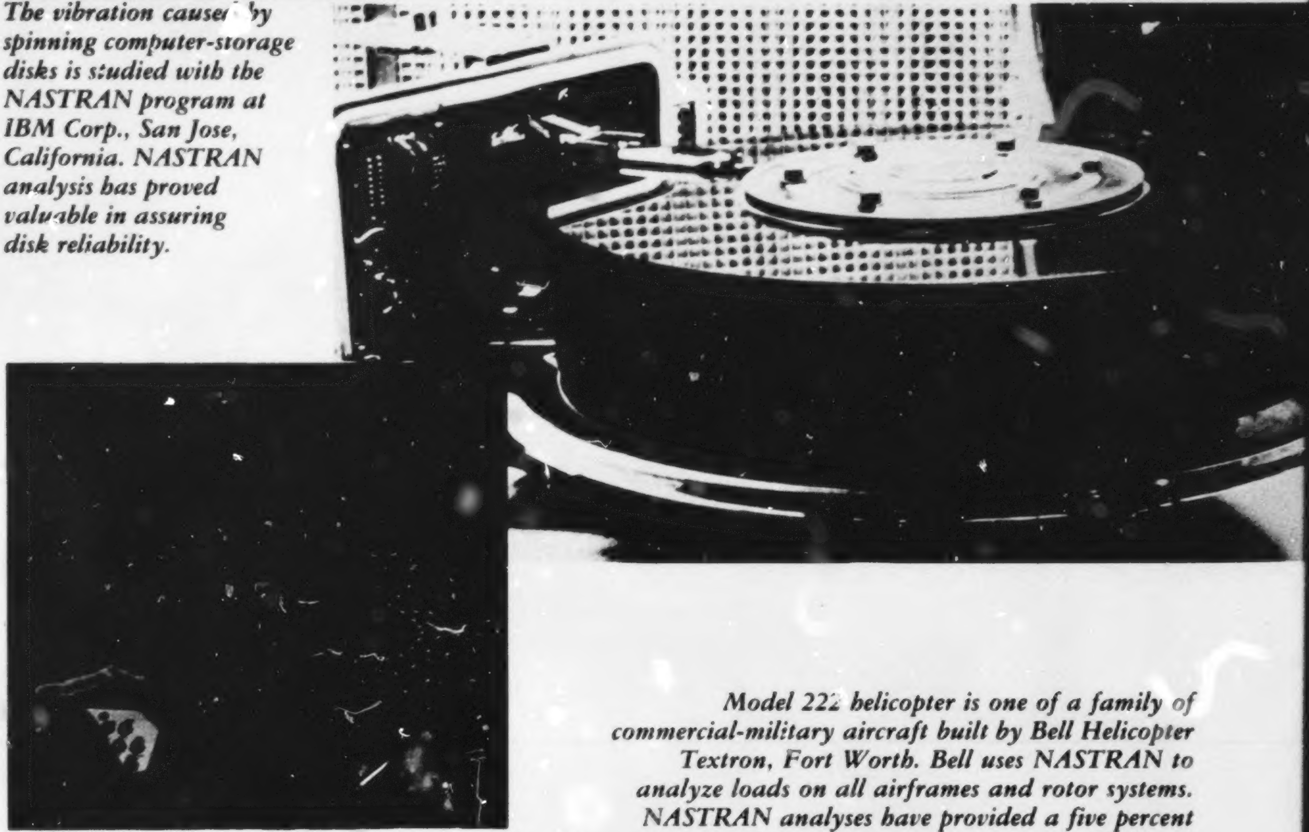


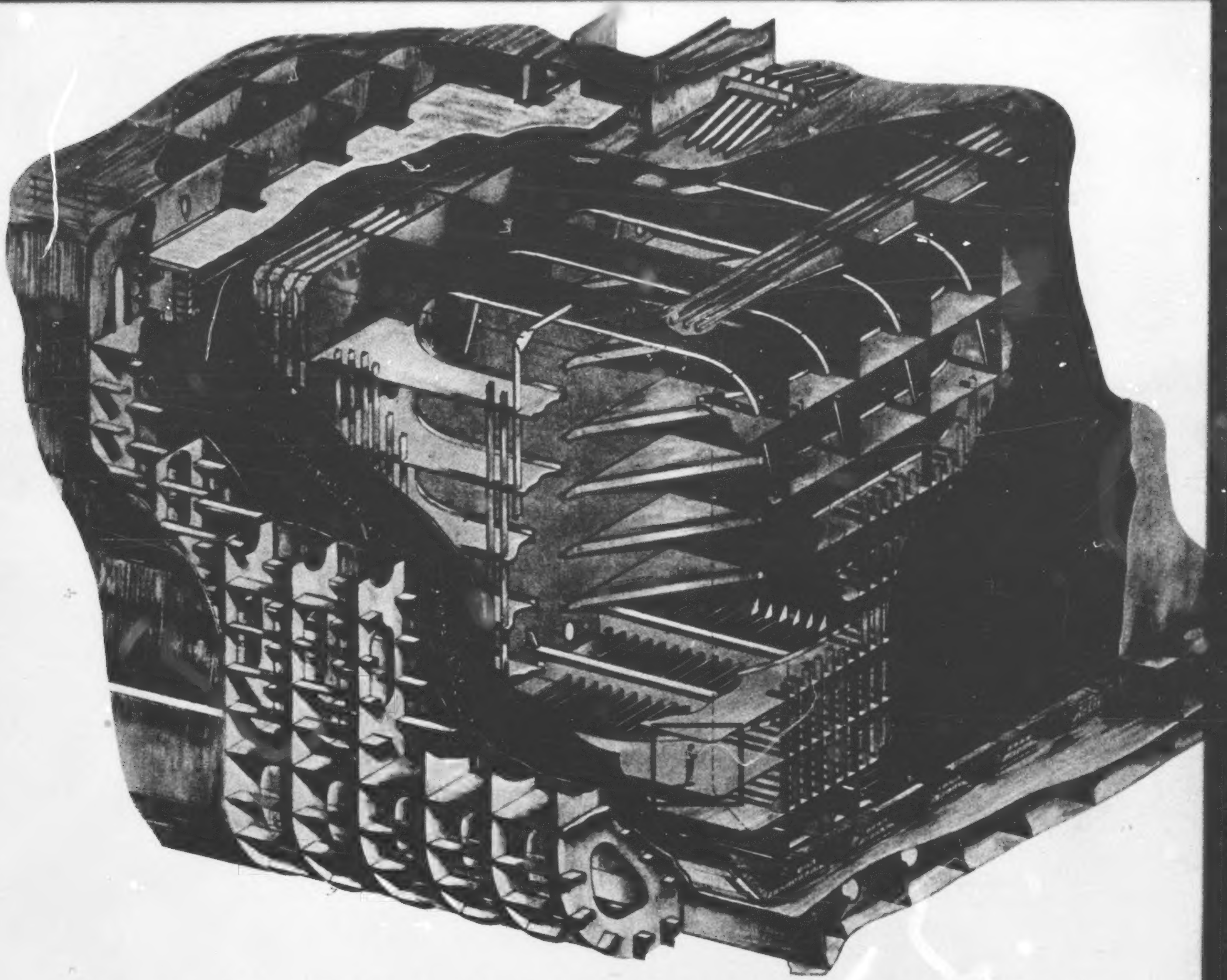


Cadillac Seville was the first General Motors car designed by the company's Vehicle Structure Analysis Program, based in part on NASTRAN. The computer program improved the car's ride within weight limits and saved development time. Success of the Seville inspired the company to extend computer analysis to the entire GM line.

The vibration caused by spinning computer-storage disks is studied with the NASTRAN program at IBM Corp., San Jose, California. NASTRAN analysis has proved valuable in assuring disk reliability.



Model 222 helicopter is one of a family of commercial-military aircraft built by Bell Helicopter Textron, Fort Worth. Bell uses NASTRAN to analyze loads on all airframes and rotor systems. NASTRAN analyses have provided a five percent savings in airframe structure weight in addition to saving development time. An example: under previous methods, Bell needed 4,550 man-hours to analyze five load conditions per helicopter; with NASTRAN, only 1,675 man-hours are required for 36 load conditions per helicopter.



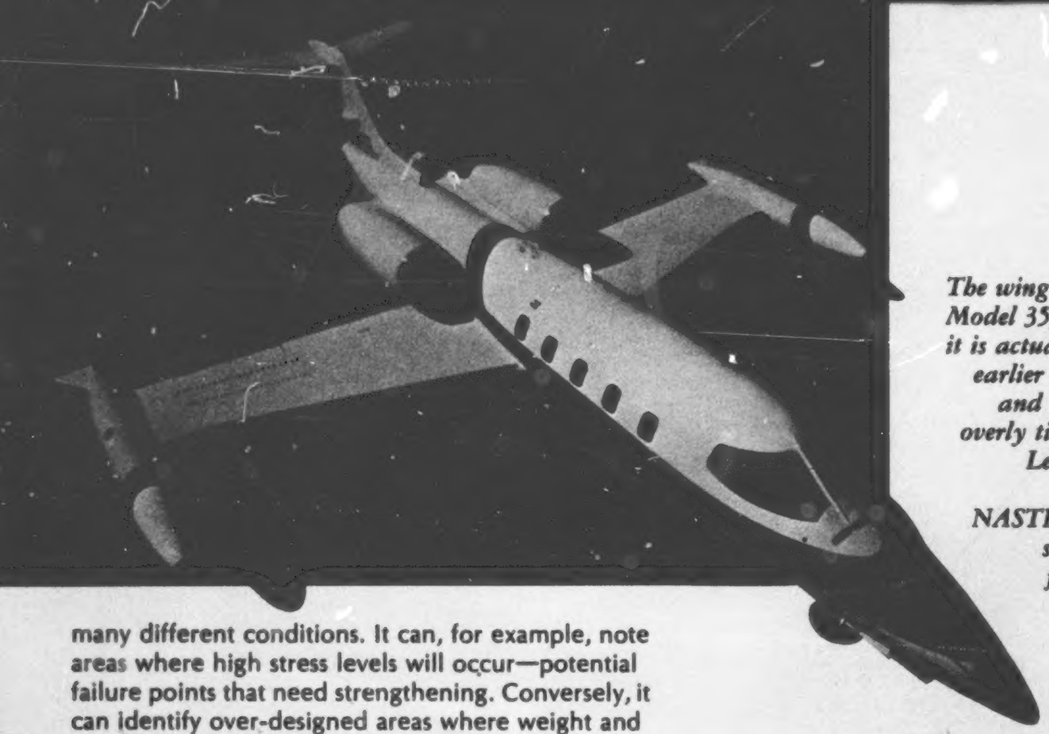
An LNG tank, designed by Conch LNG, Morristown, N.J. and constructed by Avondale Shipyards Inc. is built into a ship's hull to carry liquefied natural gas at extremely low temperatures. Each of three new Avondale ships has five huge Conch tanks; the largest holding 30,000 cubic meters of LNG. NASTRAN helped analyze such factors as reaction of components to changing temperatures and the structural behavior of tanks under ship motions at sea.

of dollars. In most instances the gain is more modest, though still significant. Because NASTRAN is widely employed, it represents an enormous national economic benefit. One study estimated that, in the period from 1971 to 1984, NASTRAN will return more than $700 million to the U.S. economy.

NASTRAN is an offshoot of the computer-design technique used in construction of airplanes and spacecraft. In this technique engineers create a mathematical model of the aeronautical or space vehicle and "fly" it on the ground by means of computer simulation. The technique enables them to study performance and structural behavior of a number of different designs before settling on the final configuration and proceeding with construction.

From this base of aerospace experience, NASA-Goddard developed the NASTRAN general purpose computer program, which offers an exceptionally wide range of analytic capability with regard to structures. NASTRAN has been applied to autos, trucks, railroad cars, ships, nuclear power reactors, steam turbines, bridges, and office buildings. NASA-Langley provides program maintenance services regarded as vital by many NASTRAN users.

NASTRAN is essentially a predictive tool. It takes an electronic look at a computerized design and reports how the structure will react under a great



The wing of this Gates Learjet Model 35/36 looks simple, but it is actually complex. Because earlier methods of designing and testing the wing were overly time-consuming, Gates Learjet Corp., Wichita, Kansas, developed a NASTRAN wing model for structural analysis of future versions of the popular 10-place business jet.

many different conditions. It can, for example, note areas where high stress levels will occur—potential failure points that need strengthening. Conversely, it can identify over-designed areas where weight and material might be saved safely. NASTRAN can tell how pipes stand up under strong fluid flow, how metals are affected by high temperatures, how a building will fare in an earthquake or how powerful winds will cause a bridge to oscillate.

NASTRAN analysis is quick and inexpensive. It minimizes trial-and-error in the design process and makes possible better, safe, lighter structures while affording large-scale savings in development time and materials. Some examples of the broad utility NASTRAN is finding among industrial firms are shown on these pages.

Sikorsky Aircraft of Stratford, Connecticut, NASTRAN-modeled the fuselages of three of its helicopters, including the S-76. Analyses included vibrational stress and the amount of bend and twist that the helicopters would experience in various maneuvers. The company found NASTRAN highly cost-beneficial and plans to use it in design of all future aircraft.

A Bell Aerospace Textron technician is "lapping"—fine polishing—a delicate space instrument part to get precise tolerance. The polishing device, first developed for precision grinding needs of the Saturn V moonbooster's guidance system, is the Abernathy lap, which allows extremely accurate finish polishing in a fraction of the time required by earlier methods. In photo at left a penny is balanced on a lapped copper disk.

Abernathy's Lap

You probably have never heard of Abernathy's Lap. It's an interesting story of how small business, as well as big industry, benefits from aerospace spinoff. In this case the business is very small in terms of personnel—one person—but substantial in output.

A lap in this instance is not a midriff but a tool for precision polishing and grinding. During the Saturn V moonbooster program, Marshall Space Flight Center found a need for a better lap. The need arose from the exquisitely precise tolerances required for parts of the launch vehicle's guidance and control system. So William J. Abernathy, a former Marshall employee, built a better lap; he invented a method for charging aluminum lap plates with diamond powder, then hard-anodizing them. The resulting lap produces a high polish on materials ranging from the softest aluminum to the hardest ceramics. It operates faster, wears longer and requires less reworking.

Abernathy got NASA's permission to obtain a personal patent and he formed the one-man Abernathy Laps Co. in Huntsville, which produces a variety of laps. One of Abernathy's customers is Bell Aerospace Textron, Buffalo, which uses the laps to finish polish delicate instrument parts produced for NASA's Viking and other space programs. Says a Bell official: "Time needed (with the Abernathy lap) is a fraction of that required by conventional methods. The result is extremely accurate flatness and surface finish."

Abernathy is providing laps for other manufacturing applications and for preparation of metallurgical specimens. The business is small but steady, and Abernathy plans expansion into other markets.

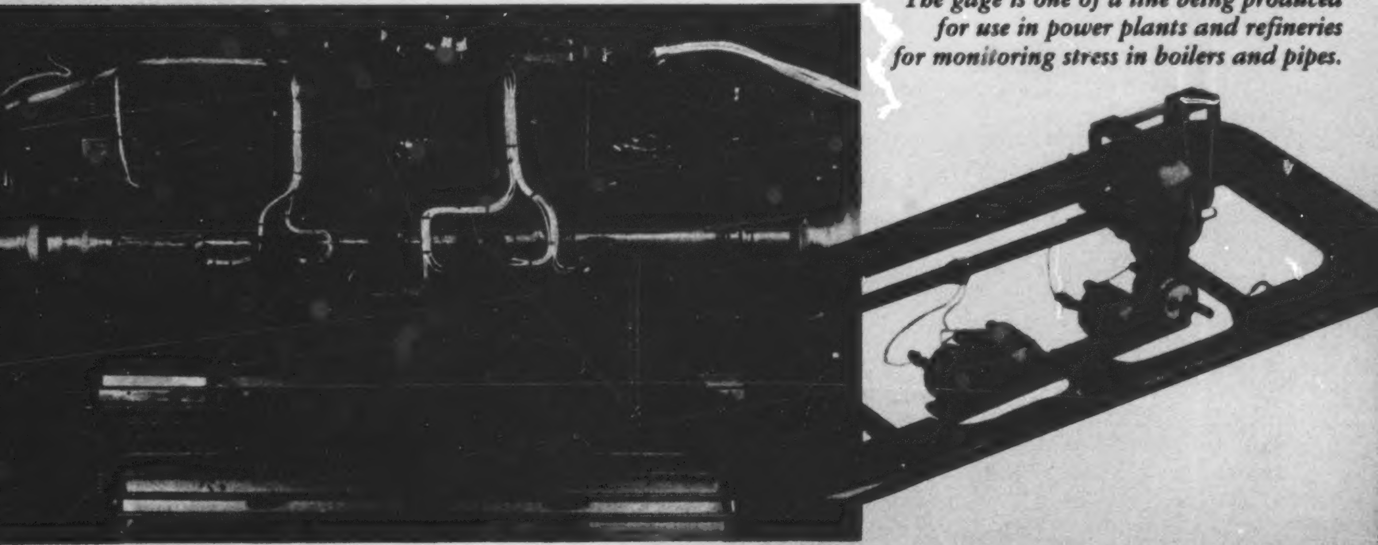
Other Industrial Aids

In another industrial spinoff, O. Z. Gedney Co., Terryville, Conn., found the answer to a problem in a NASA Tech Brief describing research in adhesive bonding for the Space Shuttle. Gedney, which makes electrical fittings for industrial plants, was developing a new "fire stop," a device that prevents the spread of fire through holes where cables and pipes penetrate fire barriers in buildings.

The company wanted to bond a metal disc on the fire stop to a layer of "instumescent" material—material that swells under heat and fills the gap caused by melted cable insulation, thus blocking passage of fire and smoke. At the company's request, NASA supplied a technical information package which identified the best adhesive and the proper bonding technique. The fire-stop fitting is now in production.

Technology developed by NASA's Dryden Flight Research Center in California, was incorporated into new high-temperature strain gages produced by Hitec Corp., Westford, Conn. The technology provides a method of compensating for erroneous strain measurements caused by expansion of metals at high temperatures. The Dryden system, developed under contract by The Boeing Co., Seattle, cancels out heat expansion strain so that only stress-induced strain is measured by the sensor.

Hitec obtained a license to use the NASA/Boeing technology in its new gages whose principal use is in power plants and refineries for monitoring stress in boilers and pipes.



This test specimen in a liquid-sodium facility at Oak Ridge National Laboratory uses special gages to measure strain at 1100° F. Metal expansion at high temperatures can cause erroneous strain measurements, but this gage automatically cancels out heat expansion strain to provide totally accurate readings. The gage is one of a line being produced for use in power plants and refineries for monitoring stress in boilers and pipes.

Multimeters are devices in wide use for routine testing of industrial electronic equipment. Generally, these instruments provide digital readouts of voltage and resistance measurements to insure that the equipment is performing properly. There is also a need for measuring surface temperature of the equipment; many failures can be predicted and avoided by periodically monitoring temperature. Until recently, precise temperature measuring devices were unwieldy and posed operating problems. The instrument pictured represents a unique solution. It is a Model 12T Temperature/Digital Multimeter, produced by Logical Technical Services Corp., N.Y., which combines in a single small instrument the ability to measure temperature as well as voltage and resistance. Key to its development was a NASA Tech Brief describing new diode sensor technology. Use of the diode sensor, tiny in comparison with other temperature sensors, enabled Logical Technical Services to design a compact, hand-held instrument that instantly shows temperature readings in a readout window like the face of a digital watch. The low cost device has many uses, ranging from quick temperature monitoring of hot components in electronic systems to checking temperature of such food processing equipment as grills, ovens and refrigerators.

Technology Utilization

How does the NASA Technology Utilization Office make new technology available and encourage its use by others?

NASA facilitates technology transfer

Activities on a nationwide basis promote effective utilization of new technology.

Aerospace spinoffs rarely occur automatically. They are an outgrowth of dynamic interactions of people —from space technologists and inventors to the ultimate users in industry. Between these two extremes a new kind of professional works in government, education, and industry constantly seeking opportunities to reapply and utilize aerospace technology in new ways. Technological gatekeepers provide a viable link between the producers of technology and its potential users, in effect "catalyzing" the transfer process.

The essential role of imaginative catalyzers to stimulate secondary utilization of aerospace technology was recognized early in NASA's history. NASA established its technology utilization program in 1962 and since then, has assisted industry, states, and local governments in bridging the sometimes formidable gap between space research advances and their use here on earth.

The Technology Utilization Office has organized its activities on a nationwide basis to promote effective utilization of the vast amounts of new technology and other technical information generated by aerospace research and development programs.

Why Technology Utilization?

In drafting the legislation that formed NASA, Congress recognized the potential value of knowledge to be generated in pursuit of the exacting requirements of space exploration, by establishing the following goal:

"The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof"

An awareness of three separate, but related, considerations of the technology transfer process led to establishing the technology utilization program:

1. Rigid requirements of space research and development provide incremental advances in the state-of-the-art that can be useful to others.
2. Products and processes are seldom, if ever, applied in the form in which they were developed to meet space-mission objectives.
3. The large volume of technical information generated from space research represents a valuable resource of use to industry.

The goal of the Technology Utilization Office, headquartered in Washington, is simply to bring about the secondary use or new application of technology already developed and paid for by the taxpayer. Less obvious are the principal mechanisms and strategies employed by the office to transfer technology to both the private and public sectors.

Technology utilization officers located at each of the 10 NASA field centers act as regional program managers and extend the Technology Utilization Office's catalyzing function by implementing its policies and projects in the areas they serve.

Getting The Word Out

"Each contract . . . shall contain effective provisions under which such party shall furnish . . . a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work"

—National Aeronautics and Space Act of 1958

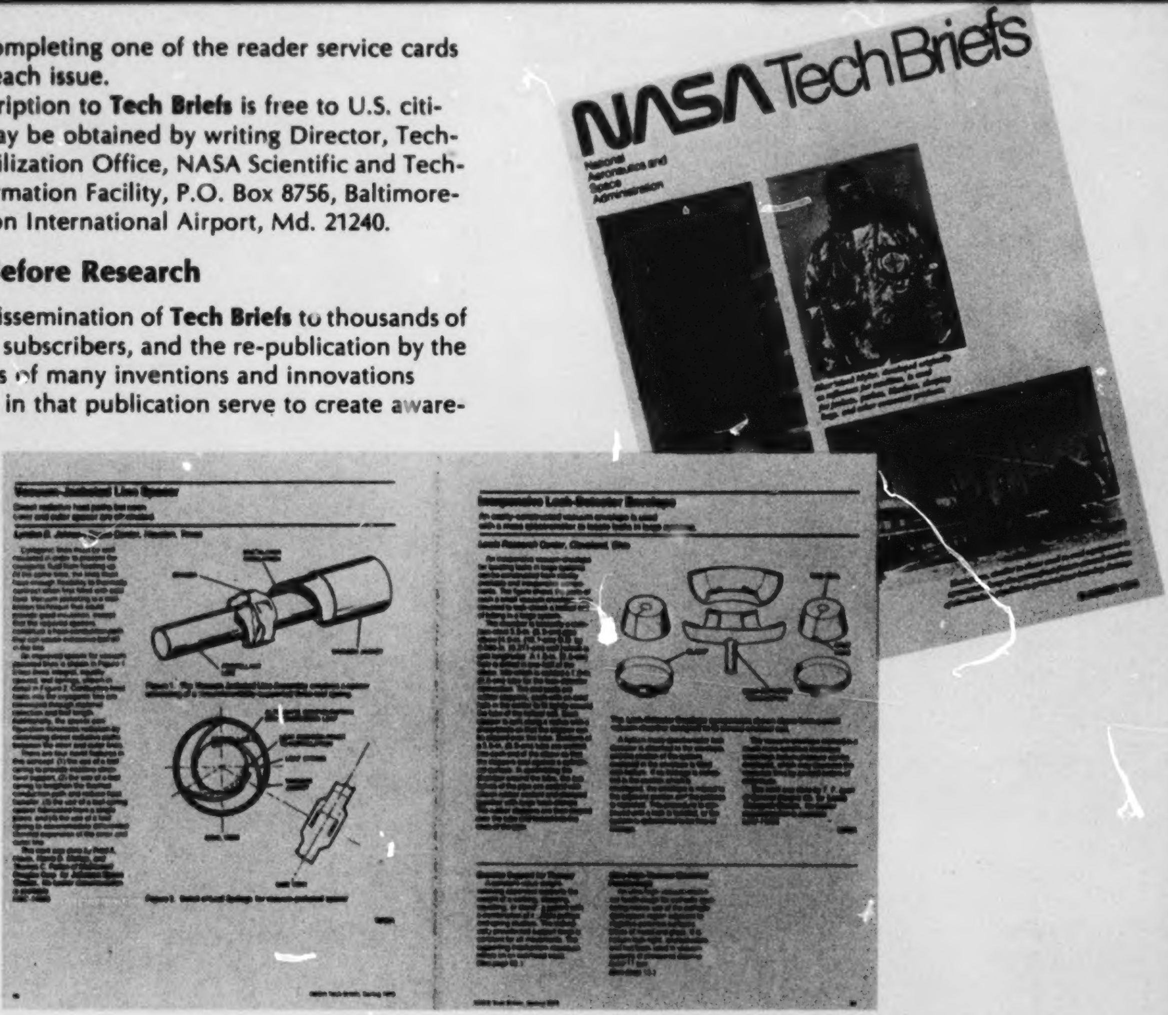
The excerpt above gives NASA the authority to require all R&D contractors to document and report new technology. NASA contracts are unique in this respect, and it is this requirement that forms the basis for the innovations and improvements that are announced in **Tech Briefs**, a two-color publication that is issued quarterly. Intended for non-aerospace users, it contains not only the familiar Tech Briefs but also information concerning the type of innovations that previously appeared in Technology Compilation booklets. Each issue contains information on more than 100 innovations, concepts, publications and computer programs.

Tech Briefs also contains a section entitled "New Product Ideas" which focuses on innovations thought to have special potential for commercialization. Each issue contains a comprehensive index; a cumulative index is published annually. Readers may obtain more detailed technical information on an item by completing one of the reader service cards found in each issue.

Subscription to **Tech Briefs** is free to U.S. citizens. It may be obtained by writing Director, Technology Utilization Office, NASA Scientific and Technical Information Facility, P.O. Box 8756, Baltimore-Washington International Airport, Md. 21240.

Search Before Research

The dissemination of **Tech Briefs** to thousands of individual subscribers, and the re-publication by the trade press of many inventions and innovations contained in that publication serve to create awareness of NASA technologies available for adaptation and use by others. However, personal interaction often is required to transfer space technology. Toward that end the Technology Utilization Office has established a network of industrial applications centers, with principal offices at seven universities across the nation, to provide information retrieval services and technical assistance to industry.



NASA's quarterly TECH BRIEFS, free to U.S. citizens, stimulates technology transfer by disseminating information on new developments stemming from aerospace research. A special section focuses on innovations deemed to have particular potential for commercialization. On request, more detailed information is provided to interested readers.

The network of industrial applications centers serves industry both by searching the literature and by helping to evaluate and apply the results. Searching what has become, by far, the world's largest technical data bank—and applying the resultant information selectively to industry's problems—now is daily routine for these NASA centers. The geographic coverage, of the applications center network, shown on the adjacent map, is being expanded each year. For example, off-site representatives now serve industrial clients in 13 cities and their surrounding areas. Also, technology coordinators, who assist by matching NASA expertise with client interests, are now located at 5 NASA field centers.

The network has access to more than 8 million documents, worldwide—and this vast storehouse of information is growing at the rate of 50,000 documents each month. It contains about 800,000 space-related reports as well as 10 times that many documents from private and non-space governmental sources.

Computer Programs

The Computer Software and Management Information Center (COSMIC) at the University of Georgia collects and screens NASA computer programs, and those of other technology-generating federal agen-

cies, for their possible interest to non-aerospace organizations. Copies of the documentation and software are then placed in inventory and offered for sale to users at a fraction of their original cost.

Matching Technology With Public Needs

Application of aerospace technology to public problems often requires technology demonstrations with user participation. To assist with these tasks the Technology Utilization Office sponsors application teams staffed by professionals from a variety of disciplines. In operation since 1965, these groups are divided into biomedical and technology application teams which are located at research institutes and universities. Both go out to public sector agencies or medical facilities to learn what significant problems might be solved by the application of NASA technology. They work closely with NASA field centers and the headquarters Technology Utilization Office in their role as catalysts to bring about commercialization or institutional acceptance of products with NASA technology.

Three *biomedical* application teams work with research clinics and other medical institutions in defining significant biomedical and health care problems that might be solved by adapting space technology. Two *technology* application teams work in much the same way with public sector agencies, concentrating primarily in the fields of public safety, urban construction and safety, and transportation.

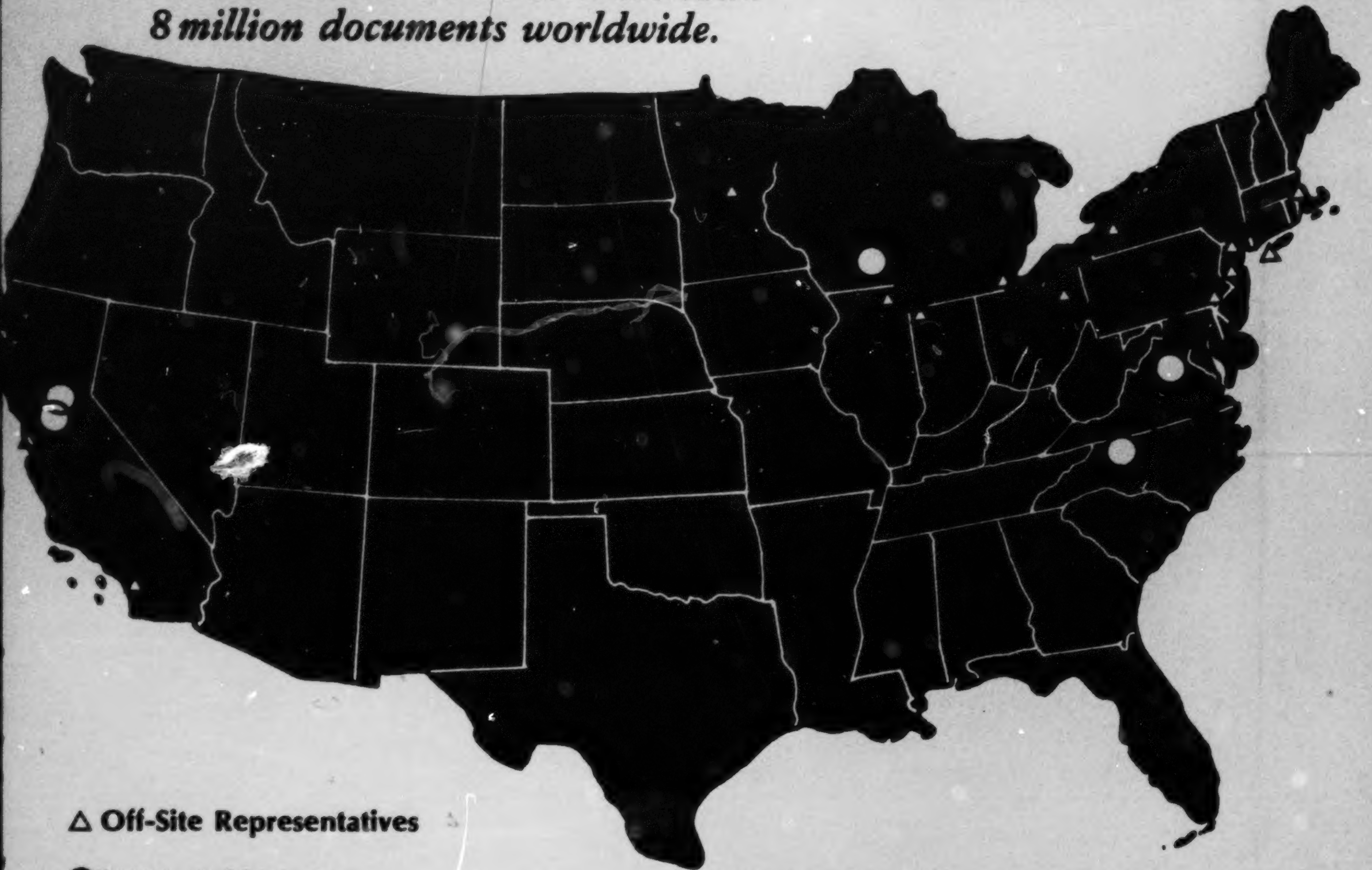
Back To The Laboratory

Aerospace technology usually must be adapted to be applied usefully to public-sector problems, which the users identify in cooperation with NASA. The Technology Utilization Office method is "applications engineering," or the effort to redesign or reengineer aerospace technology for a specific application. This activity often results in the development, evaluation, and field testing of prototype hardware.

Aerospace products and processes, with modifications, can be useful for other purposes. It is usually the technologist at a NASA field center who recognizes the opportunity for such adaptations to meet public sector needs. His proposed projects are carefully reviewed by the Technology Utilization Office for compliance with certain criteria such as technical feasibility and final product cost before funding is provided.

This brochure describes the services available to industrial firms from NASA's network of industrial applications centers, located at seven universities across the nation. With access to more than 8 million documents, the centers serve industry by searching the literature and by helping to evaluate and apply the results of the search.

The network has access to more than 8 million documents worldwide.



△ **Off-Site Representatives**

● **NASA Field Centers**

AMES RESEARCH CENTER
National Aeronautics & Space Administration
Moffett Field, Calif. 94035

Technology Utilization Officer: *Charles C. Kubokawa*
Phone: (415) 965-5554

HUGH L. DRYDEN FLIGHT RESEARCH CENTER
National Aeronautics & Space Administration
P.O. Box 273
Edwards, Calif. 93523

Technology Utilization Officer: *Clinton T. Johnson*
Phone: (805) 258-3311, Ext. 568

GODDARD SPACE FLIGHT CENTER
National Aeronautics & Space Administration
Greenbelt, Md. 20771

Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 982-6242

LYNDON B. JOHNSON SPACE CENTER
National Aeronautics & Space Administration
Houston, Texas 77058

Technology Utilization Officer: *John T. Wheeler*
Phone: (713) 483-3809

JOHN F. KENNEDY SPACE CENTER
National Aeronautics & Space Administration
Kennedy Space Center, Fla. 32899

Technology Utilization Officer: *Raymond Cerrato*
Phone: (305) 867-2780

LANGLEY RESEARCH CENTER
National Aeronautics & Space Administration
Langley Station
Hampton, Va. 23665

Technology Utilization & Applications Programs Officer: *John Samos*
Phone: (804) 827-3281

LEWIS RESEARCH CENTER
National Aeronautics & Space Administration
21000 Brookpart Road
Cleveland, Ohio 44135

Technology Utilization Officer: *Paul Foster*
Phone: (216) 433-4000, Ext. 6422

GEORGE C. MARSHALL SPACE FLIGHT CENTER
National Aeronautics & Space Administration
Marshall Space Flight Center, Ala. 35812

Director, Technology Utilization Office: *Aubrey D. Smith*
Phone: (205) 453-2224

NASA JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, Calif. 91103

Technology Utilization Officer: *John C. Drane*
Phone: (213) 354-6420

WALLOPS FLIGHT CENTER
National Aeronautics & Space Administration
Wallops Island, Va. 23337

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (703) 824-3411, Ext. 2201

○ NASA Biomedical Application Teams

RESEARCH TRIANGLE INSTITUTE (RTI)
P.O. Box 12194
Research Triangle Park, N.C. 27709

Richard Scearce, Ph.D., director
Phone: (919) 549-8311, Ext. 2640

STANFORD UNIVERSITY SCHOOL OF MEDICINE
Cardiology Division
Biomedical Technology Transfer
701 Welch Road, Suite 3303
Palo Alto, Calif. 94303

Dr. Donald C. Harrison, director
Phone: (415) 498-5935

ADVISORY CENTER FOR MEDICAL TECHNOLOGY & SYSTEMS
University of Wisconsin
1500 Johnson Drive
Madison, Wisc. 53706

Norman E. Huston, Ph.D., director
Phone: (608) 263-1550

○ NASA Technology Application Teams

PUBLIC TECHNOLOGY INC.
1140 Connecticut Ave., N.W.
Washington, D.C. 20036

Joseph Carlson, director
Phone: (202) 452-7804

STANFORD RESEARCH INSTITUTE
333 Ravenswood Ave.
Menlo Park, Calif. 94026

Tom Anyos, Ph.D., director
Phone: (415) 326-6200, Ext. 2864

▲ Industrial Applications Centers

AEROSPACE RESEARCH APPLICATIONS CENTER (ARAC)
1201 East 38th Street
Indianapolis, IN 46205

E. G. Buck, director
Phone: (317) 264-2644

KNOWLEDGE AVAILABILITY SYSTEMS CENTER (KASC)
University of Pittsburgh
Pittsburgh, PA 15260

Edmond Howie, director
Phone: (412) 624-5211

NEW ENGLAND RESEARCH APPLICATION CENTER (NERAC)
Mansfield Professional Park
Storrs, CT 06203

Daniel Wilde, Ph.D., director
Phone: (203) 486-4533

NORTH CAROLINA SCIENCE AND TECHNOLOGY RESEARCH CENTER (NC/STRC)
P.O. Box 12235
Research Triangle Park, NC 27709

Peter J. Chenery, director
Phone: (919) 549-8291

TECHNOLOGY APPLICATIONS CENTER (TAC)
University of New Mexico
Albuquerque, NM 87131

Stanley Morain, Ph.D., director
Phone: (505) 277-3622

WESTERN RESEARCH APPLICATIONS CENTER (WESRAC)
University of Southern California
University Park
Los Angeles, CA 90007

Radford King, director
Phone: (213) 746-6132

TECHNOLOGY USE STUDIES CENTER (TUSC)
Southeastern State University
Durant, Oklahoma 74701

C. Henry Gold, Ph.D., director
Phone: (405) 924-0121, Ext. 413

■ COSMIC

112 Barrow Hall
University of Georgia
Athens, Ga. 30602
Walter McRae, Ph.D., director
Phone: (404) 524-3265

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